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Commonwealth of Massachusetts

Executive Office of Environmental Affairs

100 Cambridge Street, Boston, 02202

WILLIAM F. WELD
GOVERNOR
ARGEO PAUL CELLUCCI
LIEUTENANT GOVERNOR
TRUDY COXE
SECRETARY

Tel: (617) 727-9800
Fax: (617) 727-2754

RECEIVED
DOCUMENTS COLLECTION

To: Governor William F. Weld
From: Secretary Trudy Coxe
Date: March 22, 1995
Re: Aquaculture

SUMMARY: Massachusetts Marine Aquaculture White Paper

- The Massachusetts marine aquaculture industry is small when compared to other New England states. Connecticut is the largest marine aquaculture producing state in the Northeast with estimated farm gate sales of $61.7 million, primarily from oyster sales. The state of Connecticut controls the intertidal area, and began giving grants many years ago. Maine is the second largest aquaculture producing state with farm gate sales of $42.9 million, largely from pen-reared salmon. Massachusetts estimated annual production value is $8 million. The dominant farmed species (in order of economic value) are: Northern Quahog, oyster, trout, hybrid striped bass, scallops, baitfish/other fish and tilapia. Trout, striped bass, baitfish/other fish and tilapia are all presently grown in inland facilities in this state.

- The potential growth of the marine aquaculture industry is dependent on many environmental parameters - tidal range, exposure, predation, disease, flushing rates, temperature, and water quality. Non-environmental parameters affecting potential industry expansion include federal, state and local laws/regulations, public perception, lack of policy and technical guidelines, business climate, and marketing initiatives. Traditionally ME and CT have been proactive in encouraging aquaculture, as have other major aquaculture producing states both nationwide and worldwide.

- In Massachusetts, marine aquaculture activities fall within the purview a number of regulatory programs (local, state and federal). No single government program or agency is responsible for the review and permitting of these activities. Therefore little overall coordination and minimal direct government support exists to specifically address the industry needs. The existing permitting structure is inefficient for the applicant, as well as the government agencies charged with reviewing the activities.

- Siting concerns, tideland ownership, poor water quality, environmental impacts and conflicting use issues at the local level have contributed to controversies for the marine aquaculture industry. The recent Supreme Judicial Court decision on Pazolt vs. Division of Marine Fisheries et al highlighted the ownership issue when it held that

aquaculture was not part of the historic public trust right of fishing. Therefore aquaculturists must obtain permission from the private property owner in order to practice intertidal aquaculture. Coastal communities charged with administering shellfish grants are not prepared to address the industry's expansion efforts. Controversies regarding private versus public access to these resources are escalating.

- Representatives of the aquaculture industry point out that the state lacks a clear policy which encourages aquaculture as well as a lead agency charged with technical assistance, marketing and regulatory support for the industry. Representatives recommend that government resources need to be directed to enhancing aquaculture opportunities and eliminating conflicts (e.g. targeting areas within the coastal zone ideally suited for industry expansion).

- Beneficial aspects of the marine aquaculture industry include the industry's contribution to the economies of coastal communities which have few year-round "green" economic opportunities. Marine aquaculture opportunities could provide some employment opportunities for a portion of the displaced ground fisherman. Secondary businesses which benefit from increased aquaculture include gear suppliers, netmakers, wholesalers, boatyards, etc.

- Marine aquaculture requires little in terms of municipal infrastructure to succeed.

- Wholesalers and restaurant industry leaders indicate a greater demand for "farmed" products to ensure a steady supply of fresh, contaminant free seafood on a year-round basis.

ACTION PLAN: Massachusetts Aquaculture
EOEA Strategy and Timeframe

Strategy:

EOEA, through the MA Coastal Zone Management (MCZM) office, has organized three Working Groups to address the three major areas identified in the White Paper as needing attention: Regulatory Reform, Environmental Review and Economic Development. These groups are meeting on an expedited schedule to develop state strategies for the three issue areas. Each group has already held several meetings and is making good progress on marine aquaculture issues. Subcommittees for inland aquaculture, to be organized by the Division of Fisheries and Wildlife (DFW), will be established for the Regulatory Reform and Environmental Review Working Groups, as inland aquaculture has its own unique set of issues. This summer, a final version of the White Paper and statewide Aquaculture Strategic Plan will be developed.

A Steering Committee made up of Jim Kane, Trudy Coxe, Gloria Larsen, EOEA agency heads, industry representatives and non-profits will oversee the Working Group progress and Strategic Plan development. The Steering Committee will meet monthly with the chairs from each of the Working Groups.

Utilizing the White Paper as a departure point, three Working Groups will assist EOEA staff in developing recommended strategies for 1) Regulatory Reform; 2) Environmental Review 3) Economic Development.

The **Regulatory Reform Working Group** has met four times and has meetings scheduled through April. Susan Snow-Cotter (CZM), Bob Golledge (DEP) and Mark Tisa (DFW) are coordinating this group. This group is tasked with developing a conceptual streamlined permit process for different types of aquaculture which is responsive to a range of public concerns. The group has prioritized their work as follows: 1) intertidal shellfish culture, 2) subtidal shellfish, 3) finfish culture, 4) hatcheries, 5) ponds, 6) recirculating systems (tanks), 7) federal-EEZ culture.

The **Environmental Review Working Group** will develop a strategy which encourages aquaculture while ensuring adequate environmental protection. As part of this effort, the group will develop a water quality monitoring protocol (both baseline and ongoing) for various types of aquaculture and determine appropriate siting criteria. This group will examine the potential of mapping areas appropriate for aquaculture at the harbor, town and state levels. Jim Fair (DMF) and Harlyn Halverson (U-Mass/Dartmouth) will co-chair the marine subcommittee of this group, and Mark Tisa will chair the inland subcommittee.

The **Economic Development Working Group's** mission is to identify economic constraints and opportunities for the Massachusetts aquaculture industry and farmed products. The group will examine the potential of marketing cooperative, financing options and recommend the appropriate role for the state in promoting this industry. Commissioner Jay Healy (DFA), Lisa Standish (MOBD) and Priscilla Brooks (Marine Resource Economist, Conservation Law Foundation) will head this group. Marine and inland aquaculture issues will both be considered by this Working Group.

Timeframe:

March 1995

Working Group meetings:
- Regulatory Reform - 3/9 & 3/21
- Economic Development - 3/14 & 3/28
- Environmental Review/Monitoring - 3/3 & 3/16 & 3/30

Aquaculture Steering Committee kickoff meeting - March 28, 4:30pm

April 1995

Working Group meetings:
- Regulatory Reform - 4/5 & 4/13 & 4/27
- Economic Development - 4/11 & 4/25
- Environmental Review - TBA

Regional public meetings - Cape Cod, Vineyard, South Shore - TBA

Public comment period on White Paper closes - 4/30

Steering Committee - April 27, 3:00pm

May 1995

Working Group meetings:
- Regulatory Reform - TBA
- Economic Development - 5/9 & 5/16
- Environmental Review - TBA

Regional public meeting - North Shore

Steering Committee - May 25, 4:00pm

June 1995

Working Group meetings:
- Regulatory Reform - TBA
- Economic Development - TBA
- Environmental Review - TBA

Final development Draft Strategies - 6/23

Steering Committee - Present Draft Strategies - June 29, 3:00pm

July 1995

Finalize the Massachusetts Aquaculture Strategic Plan and integrate in
White Paper - July 15.

Present Massachusetts Aquaculture Strategic Plan to Steering Committe
Secretary Trudy Coxe and Governor Weld - late July

Massachusetts Aquaculture Steering Committee Membership:

Jim Kane - Governor's Office
Secretary Trudy Coxe - EOEA
Leo Roy - EOEA
Secretary Gloria Larson - EOEcA
Senator Bruce Tarr
Senator Henri Rauschenbach
Congressman Studds representative: Mark Forrest
Senator Kerry representative: Jennifer Miller
Acting Commissioner Tom Powers - DEP
Peg Brady - CZM
Commissioner Jay Healy - DFA
Chancellor Peter Cressy - UMass
Dr. Harlyn Halverson - UMass
Phil Coates - DMF
Jim Fair - DMF
Wayne MacCullum - F&W
Mark Tisa - F&W
Lisa Standish - MOBD
Bob Golledge - DEP
Karl Rask - MA Aquaculture Association
John Richards - industry representative
Roger Berkowitz - Legal Seafoods
Joseph Milano - Union Oyster House
John Reid - Bioshelters, Inc.
Joshua Goldman - Aquafutures
Rob Garrison - Nantucket Research & Education Foundation
Pricilla Brooks - Conservation Law Foundation

Working groups membership:

Regulatory Reform Working group:

Susan Snow-Cotter, CZM

Bob Golledge, DEP-DWW

Mark Tisa, DFW

Dave Shepardson, MEPA

Jim Fair, DMF

Deb Graham, DEM

Bill Blanchard, DFA

Grant Kelley, ACOE

Mike Marsh, EPA

Chris Mantzaris & Eric Nelson
National Marine Fisheries Service

Paul Bagnell
Edgertown Shellfish Constable

Paul Somerville
Wellfleet Shellfish Constable

Pat Eldridge & Kathleen Creedon - Sen. Rauschenbach's staff

John Richards
Industry Representative

Karl Rask
Massachusetts Aquaculture Association

Joshua Goldman
Aquafutures

John Reid
Bioshelters Inc.

Mark Simonitsch
Fish Weirs, Inc.

Economic Development Working Group:

Jay Healy & Bill Blanchard
Department of Food and Agriculture

Lisa Standish & Paul Sisson
Mass. Office of Business Development

Priscilla Brooks
Conservation Law Foundation

Scott Soares
SERPED

William P. Burt
Marine Resources Specialist

Jean Fraiser
Northeast Regional Aquaculture Ctr.

Gary Glenn
Mass. Foundation for Excellence in Marine and Polymer Sciences, Inc.

Karl Rask
Massachusetts Aquaculture Association

Rob Garrison
Nantucket Research and Education Foundation

Alice Boyd
Cape Cod Resource/ Mass. Aquaculture Association

Ann Homme
Fair Acres Farm

Richard Kraus
Aquaculture Research Corp.

Richard Taylor
Industry Rep.

Patricia Eldridge - Sen. Rauchenbach's staff

Environmental Review Working Group:

Harlyn Halverson
UMASS/ Dartmouth

Mark Tisa
DFW

Jim Fair
Division of Marine Fisheries

Dave Shepardson
MEPA

Judy Pederson
MIT Sea Grant

Dale Leavitt
Woods Hole Sea Grant

Marie Studer
CZM

Pat Hughes
Cape Cod Commission

Phil Colorusso
EPA - Region I

Ken Bergstrom
Mass. Aquaculture Association

Eric Nelson
National Marine Fisheries Service

John Todd (invited)
Ocean Arks International

**** DRAFT ****

MASSACHUSETTS
MARINE AQUACULTURE WHITE PAPER

COASTAL ZONE MANAGEMENT OFFICE
Executive Office of Environmental Affairs
100 Cambridge St.
Boston, MA 02202
(617) 727-9800

February 14, 1995

WHITE PAPER ON MARINE AQUACULTURE

Characterization of Marine Aquaculture in Massachusetts

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Appendix III - Summary of Relevant Aquaculture Laws of CT, RI & ME

EXECUTIVE SUMMARY

> AQUACULTURE: The manipulation of marine or freshwater organisms and/or their environment before eventual release, harvest, or capture; the controlled cultivation and harvest of aquatic animals and plants. (USDA National Aquaculture Development Plan, 1983).

In Massachusetts, marine aquaculture is presently limited to the cultivation of shellfish for commercial, research, and propagation purposes. There are no coastal fish farms or ocean ranches in the state and only very limited work, primarily for research purposes, is dedicated to seaweed culture. Proposals for offshore fish farms and shellfish culture have just recently been proposed in the state. Although other forms of aquaculture are addressed here, the emphasis is on intertidal shellfish.

The wild stock of both finfish and shellfish is currently dwindling, a trend that, despite the imposition of limits and closed seasons, has shown every indication of continuing. The recent closures of groundfishing on George's Bank are indicative of a larger problem both in Massachusetts and to some extent, worldwide. While fish stocks are undeniably declining, the demand for high quality marine protein for a variety of uses continues to grow. Aquaculture has been viewed by many as a means to address the gap between wild seafood availability and consumer demand. The development and support of the coastal aquaculture industry is therefore a priority for the state of Massachusetts, not only in terms of increased seafood supply but also as a potential source of employment for displaced fishermen.

State aquaculture programs are a reflection of local attitudes for or against the industry. These attitudes are created and influenced by historic and cultural trends, traditional uses, education, environmental and economic conditions, and the manner in which a state chooses between conflicting uses and limited resources. Massachusetts has, to date, reacted to the aquaculture industry on a case by case basis with very little attention given to the larger picture. As a result, the state has been viewed by many as an impediment to growth in the industry. This viewpoint is due, in part, to a complex and duplicative permitting system as well as a paucity of technical assistance provided by state agencies.

With significant attention now being paid to the potential of the aquaculture industry, the Executive Office of Environmental Affairs, acting on behalf of the Governor, has initiated this study

to identify how the state can proactively assist the aquaculture industry. The purpose of this report is to review the status of the aquaculture industry in the state both from a biological and technological standpoint as well as from a legal/regulatory perspective.

This White Paper includes information on the biology, technology, support systems, water quality, seafood safety, legal, and economic aspects of the aquaculture industry. Problems attendant to marine aquaculture are distilled in the Conclusion section. The Recommendations-Action Plan is to be developed by the three Marine Aquaculture Working Groups (Regulatory Reform, Environmental Review/Monitoring, Economic Development/Marketing) and is expected to be available in the spring of 1995.

This report reflects the aquaculture industry today in Massachusetts in that the focus of much of the review is on shellfish with a cursory examination of finfish, seaweed and lobster culture. It should be kept in mind that the aquaculture industry in Massachusetts is in the process of rapid growth and change and that the information in this report is indicative of the situation at the time of printing (early 1995).

The White Paper is limited to addressing coastal aquaculture and the myriad of issues and concerns attendant to it. A distinction must be drawn between inland aquaculture and coastal aquaculture. Inland aquaculture utilizes ponds, tanks, and enclosures that are dependent upon the aquaculturist for maintenance of water quality, food supply, and waste removal. Inland aquaculture is generally (with the exception of state-run hatcheries and stocking facilities) conducted on private property by private culturists. The primary product of inland aquaculture is finfish.

Coastal aquaculture utilizes enclosures, cages, or pens for mobile marine species such as silver and Atlantic salmon; baskets, rafts, racks, and trays for surface culture or water column (off-bottom) culture for sessile molluscan shellfish; nursery trays and pens placed on the bottom for the cultivation and grow-out of seed shellfish or placement of cultch (natural or artificial) for attachment of molluscan spat. All coastal aquaculture uses existing, unaltered water.

The private and public interests affected by competing uses of the sea, the coast, and the tidelands raise complex issues. The alteration, whether temporary or permanent, and private use of public resources provides a broad basis for potential conflict if not managed prudently. It is the intent of this study to both characterize the state of the aquaculture industry in Massachusetts today and plan for a diverse and sustainable industry for the future.

INTRODUCTION - HISTORY OF AQUACULTURE

Massachusetts has approximately 1500 miles of coastline interspersed with rivers, estuarine systems, salt ponds, saltmarshes, and protected bays. These waters produce a variety of seaweeds, shellfish, crustaceans, and finfish. Many of the coastal waters are of high quality and have historically supported a significant commercial harvest as well as recreational fisheries and water-sports activities. The productivity of natural populations in Massachusetts is a good indicator that the quality of the state's waters is suitable for a variety of aquacultural activities.

Harvesting the sea, either through the taking of wild animals or through managed cultivation of impounded waters, tidelands, or submerged lands, is a practice that dates from before the first European settlers landed in the Bay colonies. However, the practice of rearing bivalve mollusks from the fertilized egg to the juvenile stage under controlled conditions did not become a commercially viable reality until the 1960's. Initially there were many failures, usually due to insufficient understanding of bivalve larval food requirements. Once realized, it became clear that millions of tiny clams, oysters, and bay scallops could be successfully produced in captivity.

During the 1970's, when methods of satisfying the nutritional requirements of larval and juvenile shellfish in captivity had been improved, a major focus in shellfish culture was the development of methods to assure the survival of hatchery-reared juveniles to market size. Attempting to rear shellfish from larvae to harvest size in "captivity" is not economically feasible. Various techniques were developed for culture under natural conditions, including "off-bottom" methods and the use of various materials spread on the bottom that protected the young shellfish from bottom-crawling predators.

By the 1980's, commercial shellfish hatcheries were operating successfully in New England, both publicly and privately run. Large numbers of juvenile hard clams (quahogs) and oysters were produced each year and transferred for grow-out to harvest size to tidal flats.

Today, aquaculture can be separated into two broad methods and techniques - intensive and extensive aquaculture. Intensive aquaculture subjects an organism to hatchery controlled-conditions for most of the life cycle. This form is most commonly applied to finfish. The cultivation of salmonids in "fish farms," either offshore or in inland ponds, is an example of intensive aquaculture; the fish are hatched from eggs, reared and fed in

controlled enclosures until reaching harvest size, and then harvested.

Extensive aquaculture is the manipulation in the natural environment at one or more stages of an organism's life cycle. Examples include the growing of shellfish off the bottom on and in mesh bags, sleeves, nets, floats, trays, or racks, predator control, and removal of "seed" shellfish from a nursery area to a controlled pen until growth to full harvest size is completed.

CHAPTER ONE - SHELLFISH BOTTOM AND OFF-BOTTOM CULTURE

This chapter will discuss the basic biology and production techniques for shellfish (both bottom and off-bottom culture). In addition, this chapter addresses problems inherent to shellfish aquaculture, including environmental, economic, business, legal, etc.

The exclusive form of commercial aquaculture engaged in Massachusetts to date, both privately and by several cities and towns and the Division of Marine Fisheries, is mollusk culture, employing several methods of cultivation. This chapter provides significantly more detail on shellfish than other forms of aquaculture and this is a simple reflection on the dominance of shellfish in the Massachusetts aquaculture industry. Massachusetts is not alone in its predominant interest in mollusk culture. Bivalve mollusk culture is globally the most economically successful form of marine animal aquaculture; it is at least twice as productive as finfish and crustacean culture combined. While bivalve mollusk culture is well established in the state, recent proposals indicate commercial interest in finfish (cod, salmon, and steelhead trout) as well.

BIOLOGY

Hard clams (quahogs), soft clams (steamers), oysters, bay scallops, and mussels all reproduce by spawning; the discharge of microscopic eggs and sperm into the surrounding water, triggered by increased water temperature. The number of eggs released by a single female is impressive; a mature oyster may release up to fifty-million eggs in one season.

The eggs are fertilized in the surrounding water and within a matter of hours, the embryos develop into motile, swimming larvae. The duration of the larval period varies with water temperature and generally ranges between one to three weeks (these are requirements that may be artificially manipulated in commercial hatcheries to maximize fertilization and shorten developmental periods). The larval stage is terminated by metamorphosis; the transition to the early juvenile stage, which resembles a miniature of the adult form. Because shellfish larvae are essentially planktonic organisms that drift about and are subject to dispersal by currents, winds, and wave action, they may undergo metamorphosis, or set, far from the site of initial fertilization.

The behavior of the various species begins to differ at this stage of development. The early juveniles of quahogs and soft

clams are capable of crawling on the bottom sediments. Upon finding an acceptable substrate, they dig in by means of a muscular foot. While still small, they are capable of emerging and wandering, searching for greater food sources, more desirable locations, etc. However, the remainder of their life is sedentary and spent beneath the sediment surface. Until they reach legally marketable size, clams at this stage are referred to as seed.

All bivalve mollusks (bivalves) are filter feeders, extracting their food from the surrounding water. Because they dwell in the bottom substrate, clams are equipped with siphon tubes that enable them to draw in the water from above. Unfortunately for bivalves, natural predators are numerous, including several species of crabs, snails, starfish, drills, finfish and waterfowl, many of which patrol the bottom.

Quahogs are hardy and long-lived. Soft clams, oysters, and mussels are more vulnerable to age and predation. Bay scallops are comparatively short-lived. All of these species are capable of reproduction by the end of their first full year of life.

The natural habitat of these mollusks varies considerably. The oyster and the soft clam can tolerate conditions of varying salt concentrations, adapting them to estuarine as well as ocean environments. The quahog, bay scallop and mussel prefer higher salinity and are more likely to occur in salt ponds and coves without appreciable inflows of fresh water. The soft clam, oyster, and mussel can all thrive intertidally. While the quahog may live in the tidal flats, its preferred location, along with the bay scallop, is sub-tidal.

The nature of the bottom sediments is critical to normal development and reproduction. Soft bottom muds are generally inhospitable, due to the potential for siltation and hypoxia. These soft muds might be indicative of situations where contaminants may be a problem.

Phytoplankton, an essential component of shellfish diet, depend upon the availability of inorganic nutrients as well as radiant energy for photosynthesis. Run-off from upstream sources, the addition of point-source pollutants, narrowing of embayments, and reduced water flow all impact upon these organisms. Excessive artificial enrichment (i.e. introduction of partially treated or untreated sewage or other fertilizing agents) may result in eutrophication, which degrades food sources and reduces viable shellfish habitat. The addition of nitrogenous compounds can stimulate the growth of several species of planktonic algae undesirable for shellfish food, which compete with desirable food species. In high concentrations, these algal cells can shade out natural stands of benthic plants such as eel-grass and, as they die, contribute to the accumulation of organic matter on the

bottom. As this material decomposes, the oxygen concentration in the bottom waters drops. Alternatively, bottom vegetation may be stimulated by excessive nutrients to grow in such dense concentration that tidal circulation near the bottom is reduced or eliminated, thereby inhibiting the growth of bivalves.

Despite the enormous reproductive potential of shellfish, many factors contribute to a very high mortality rate during their life cycle, most particularly during the larval and juvenile stages. Shellfish aquaculture techniques are designed to reduce these losses, by protecting shellfish at early, vulnerable stages from predation and other adverse natural phenomena as long as economically feasible.

Quahogs

The common hard shell clam, or quahog, is well adapted to life in the sea, particularly the sand and mud flats of the subtidal and lower intertidal zone. The northern quahog, *Mercenaria mercenaria*, belongs to the class *Bivalvia*, easily identifiable by two, somewhat rounded, hinged shells, protruding burrowing foot, and the purple or dark blue border found on the inside of the shell. The variety known as *M. Mercenaria notata* is widely grown in Massachusetts. It is distinguished by a chestnut brown zig-zag line of the outside of the shell. Some cultivators prefer this variant because of its faster growth rate and natural identifiability. The name *Mercenaria* comes from the historic use of the shell for making Indian money, or wampum. Beads made from the purple part of the quahog shell were the most valuable form of wampum.

The quahog spends most of its life (which can last for up to 20 years) buried into the sediments of the subtidal and lower intertidal zone, with its two siphons reaching just above the surface to feed and discharge wastes. It feeds by filtering phytoplankton from water that it pulls in over its gills with one siphon and then pumps it back out through the other. Quahogs reproduce in the same manner as most bivalves, by shooting vast quantities of sperm and eggs into the water. Here the eggs are fertilized and dispersed by the currents. Hard clams spawn when the water temperature reaches approximately 60 degrees F. Of the millions of eggs shot out by female clams, only a small percentage survive to maturity in an uncontrolled environment.

Quahogs typically grow up to four inches and sometimes larger. Commercially, there are three names, based on size; the littleneck (48mm valve length or 1.5 inches), the cherrystone (60mm valve length or 2 inches), and the chowder (greater than 75mm or 3 inches or more). Some individuals can attain sizes of up to 130mm or 5 inches.

Quahogs are the preferred food of several predator species, notably green crabs, starfish, moon snails, and horseshoe crabs.

Oysters

Two kinds of oysters are cultured in Massachusetts, the Eastern, or American oyster, *Crassostrea virginica*, and the European oyster, *Ostrea edulis*. Oysters are surface dwelling organisms and the metamorphosizing larvae search out hard clean surfaces (cultch), which may include live oysters, to which they cement themselves. Recently-set oysters are known as spat. Setting oysters, depending upon conditions, may result in heavy local concentrations in the form of bars or reefs, where competition for space is fierce. Once attached, an oyster never moves again, unless dislodged by external forces.

Oyster shells, or valves, differ in size and weight, with the right valve (the top valve) forming flat and the left (bottom valve) being heavier and cupped. The valves are joined by a ligament and the shell shape can vary widely. The size and shape of an oyster's shell is significant in aquaculture; the raw market demands a full, shapely, aesthetically-appealing shell. Shell growth largely depends upon water temperatures and culturing times will vary according to the size to be attained. For example, in Massachusetts, it can take two - four years to attain market size while in Florida, where oysters are grown year round, eighteen months is usually sufficient.

American oysters are divided into separate male and female individuals and spawn by spewing millions of eggs and sperm into surrounding waters, where external fertilization takes place. European oysters are hermaphroditic; each individual possesses male and female germ cells, and fertilization occurs inside the inhalant chamber of the oyster. The larvae then incubate in the chamber for up to ten days prior to being ejected into the surrounding waters. Immediately before setting, both types of oysters develop eye spots and a foot and begin to search out cultch to attach to. Satisfactory cultch includes any clean, hard surface (usually empty bivalve shells).

The color, texture, and quantity of the meat in the shell is very important to the raw oyster market and those qualities will vary with age, water quality, and time of harvest. Oysters will accumulate and/or metabolize almost every element contained in the water around them. The quality of the meat drops during the spawning season. After spawning, oysters build up glycogen, which provides the appearance of a "fattening" or "fat" oyster, the most desirable kind.

Oysters are subject to a variety of natural predators, an environmental hazard that may be substantially reduced by cultivation and predator-control methods. Depending upon salinity, Atlantic oyster drills, thick-lipped oyster drills, rock shells, knobbed whelks, channeled whelks, and starfish all prey on oysters.

Oysters are also subject to a variety of diseases and parasites, the most recently notorious being MSX, discussed infra. The severity of impacts by disease and parasites on oyster populations is thought to be related to water quality; higher salinity, high temperatures, and nutrient loading appear to make oysters more susceptible to disease.

Oysters provide a welcome habitat for commensal and competing organisms. Several live in or on the shell; the boring sponge, the boring clam, and the mud worm are examples. Barnacles, tunicates, and mussels (as well as other oysters) will attach themselves to the outside of the shell, as will as several species of algae. One algal species, *Codium fragile*, produces aveoliated branches filled with gas that may actually lift the oyster and carry it off with the tide.

Bay Scallops

Bay scallops, *Aequipecten irradians*, differ from clams and oysters in that they retain the ability to move actively throughout their lives. The juveniles will attach themselves to underwater eel-grass or algae through extruded filaments known as byssal threads. Their ability to move and remain above the sediment makes them less prone to bottom predation. Bay scallops eventually lose the tendency to attach themselves; they dwell on the bottom as adults, manipulating themselves through "jet propulsion" by forcefully closing their valves. Scallops less than one year old (determined by the annual growth ring) are considered seed and may not be harvested.

The bay scallop, as with other shellfish, has two shells, or valves, with the "laying" shell (the one the scallop rests on) being lighter in color and having a byssal notch or foot groove. The outer surface of a scallop shell exhibits prominent ridges and furrows, which radiate from the beak to the free margin. During the winter months, the scallop does not grow and a heavy concentric line, similar to that of a tree's annual ring, forms. Growth begins again in the spring and it is this ridge that determines the age of a scallop.

Scallops, unlike quahogs and soft clams, have only one adductor muscle, commonly referred to as the "eye." Bay scallops are hermaphroditic; all individuals possess male and female sex

organs and produce both sperm and eggs.

Bay scallops spawn in response to increases in water temperature in the spring, beginning at approximately 61 degrees F., although spawning may be induced artificially in the hatchery by increasing water temperatures; 68 - 84 degrees is the spawning range, with 74 - 76 degrees inducing spawning within fifteen minutes after placement. Bay scallops have the capacity to spawn repeatedly over a period of weeks, depending upon external conditions.

Scallop larvae go through two distinct developmental stages, during which the mortality rate is at the highest point in the life cycle. The embryonic, or sub-veliger stage is the period prior to development of a shell; the post-embryonic, or veliger stage is the period during which the larvae have developed shells but prior to attainment of full development. During this pre-adult stage, the larvae are capable of both digging and swimming.

Once the scallops "set" by way of attachment to an available surface with byssal threads, they have reached the dissoconch ("two shelled") stage and are approximately 1/3 " in size. The scallop does not reach its full internal and shell development until the plicated stage, where the radiating ridges characteristic of the adult scallop develop. Bay scallops have a much shorter life-span than do oysters, clams, or mussels. Most bay scallops do not live beyond two years and they may reach sexual maturity within six months. They also retain their free-swimming (through jet-propulsion, expulsion of water through the "ears" coupled with shell closure) and locomotive abilities, which mandates that cultivation be off-bottom, in enclosed nets, bags, or cages.

Bay scallops, like other shellfish, are filter feeders. Unlike clams, who feed from below the substrate, scallops use their gills to siphon diatoms and other planktonic matter from the surrounding water.

Scallops are not as likely to act as a vector for disease as other shellfish because the adductor muscle is the most common food product. Pathogens are typically transferred through the food chain as the result of eating the whole shellfish, including the gut, where pathogens typically accumulate. However, consumption of whole and roe-on scallops has increased dramatically over the last two years, leading to increased risk of food product contamination.

Mussels

Mussels also initially fasten themselves by byssal threads to submerged substrate at metamorphosis. Unlike scallops, mussels

retain this tendency for attachment throughout their lives. The preferred substrate for mussels is other mussels. If stressed, mussels may detach themselves and subsequently re-attach their byssal threads after finding a more desirable location.

Mussels grow most quickly when continually immersed in water since they can almost constantly feed.

All stages of mussel development appear to be influenced by water temperature. Mussels will spawn at temperatures between 62-80 degrees F., but will spawn almost continually when the temperatures remain in the 75 degree vicinity. The larvae are free-swimming, and may attach several times by means of byssal threads until a desirable location (one that is abundant in food and maintains water temperatures above 65 degrees seem to be favored) is located. Once permanently set, the larvae do not move again and the competition for space is vigorous. It is common to find mussels growing in layers of other mussels, both naturally in intertidal and sub-littoral levels, and when cultured on lines. Mussels grown in water temperatures above 65 degrees mature more quickly than those grown in colder waters, maturing in less than a year. Below that range, mussels may take up to two years to reach market size.

Bottom Culture - Overview

The practice of cultivating bottom-dwelling shellfish (most commonly hard shell clams and oysters) in nursery trays and pens from juvenile stages to maturity is collectively known as bottom culture. Since at least 1974, intensive quahog culture has been ongoing in Barnstable (62 acres), Provincetown (45 acres), Wareham (90 acres), and Wellfleet (80 acres), utilizing bottom culture on the intertidal flats.

a. <u>Species Cultured</u>

Oysters and Quahogs are commonly cultured using bottom culture techniques.

b. <u>Procedure</u>

The practice is conducted in three stages:

1. Production of Seed - very small clams (1 - 25 mm) are obtained from hatcheries (or other sources, including natural collection) where clams are cultured from initial spawning through the larval metamorphosis to the juvenile stage. Once juveniles reach the size

of 2mm, they can be marketed as "seed," although the preference is for seed greater than 8 mm, which better resist predation. The cost of hatchery seed (6-8 mm) varies from $25 to $35/100.

2. Field Planting - the seed are "planted" in net-covered boxes measuring approximately 4 feet x 8 feet x 6 inches, that are filled with "clean" sand (sand that does not contain predator species; i.e. green crabs), and are slightly elevated above the intertidal flats on legs. See Illustration at Appendix V. These boxes, known as "nursery trays" may contain up to 10,000 seed clams.

3. Grow Out - the seed are allowed to remain in the nursery trays until a size of 19 - 24mm. At this point, they are transferred to narrow, net-covered plots ("pens," or sometimes "raceways") for grow out. When the clams reach 51 - 63mm (2 - 2.5 inches) they are harvested. Gross sales of $25,000 -$35,000/acre have been reported at harvest of mature clams, 1.5 -2 years after field planting.

c. Current Bottom Culture Leases

There are approximately 646.5 acres of tidelands currently licensed for shellfish cultivation (commercial and research) in twenty-two Massachusetts cities and towns (Barnstable, Brewster, Chatham, Dennis, Duxbury, Eastham, Edgartown, Essex, Fairhaven, Falmouth, Gosnold, Mashpee, Mattapoisett, Nantucket, Oak Bluffs, Orleans, Plymouth, Provincetown, Truro, Wareham, Wellfleet, and Yarmouth). Cultivated species include, in order of economic importance, (1) quahogs, (2) American oysters, (3) bay scallops, (4) soft shell clams, (5) European oysters, (6) surf clams, and (7) blue mussels.

According to the reports submitted by municipal shellfish constables, the landed value of cultured shellfish totaled $620,000 in 1988, $1,933,000 in 1989, $906,000 in 1990, and $1,884,000 in 1991. These values are questionable at best. Not all towns with acreage under active cultivation submitted reports and chronic under-reporting is an acknowledged problem. The consensus opinion of the Massachusetts Aquaculture Association and the Massachusetts Shellfish Officers' Association is that the reporting value represents approximately 30-40% of the actual landed value.

d. Legal Issues

Due in large part to the extent of privately held tidelands in the state, much of the shellfish culture in Massachusetts is

conducted on private property. Often the culturist is not the owner of the flats under cultivation. The recent Massachusetts Supreme Court decision on Pazolt vs. Mass. has ruled that culturists must obtain permission from the owners of privately owned tidelands prior to establishing aquaculture facilities. For a discussion of the problems associated with the public use of private property, see Chapter Five.

e. Environmental Issues

The successful growth and harvesting of food-quality shellfish requires high water quality, quality that is very vulnerable to the effects of competing coastal uses.

Bottom-dwelling shellfish are filter-feeders, obtaining nutrients (phytoplankton, heterotrophic micro-organisms, minerals and dissolved organic particles) by straining them from the surrounding water when ambient temperatures are above 10 degrees C. Conditions that affect either the availability of food (i.e. toxic blooms of certain flagellates, "brown" or "red" tides that repress certain diatom populations) or the quality of the water (i.e. excessive turbidity) affects the set of spat and the growth of seed.

Shellfish are capable of filtering, along with their traditional nutrients, various pollutants and wastes from the surrounding water and substrate. Coastal development and recreational uses supply these pollutants in abundance, either through direct (point-source) discharges or from run-off (non-point source) discharges. The chronic discharge of pollutants systematically degrades the quality of the water. The results of such degradation may vary from death, mutanogenic or teratogenic effects upon shellfish, and sickness and/or death of consumers further up the food chain.

Degradation of water quality (and associated substrate degradation) includes characteristics such as lower dissolved oxygen levels, changes in temperature, changes in salinity, and changes in turbidity. All of these parameters have a direct bearing upon the quality and quantity of shellfish propagated and harvested.

Maintaining and upgrading water quality presents a host of problems. Coastal development, industrial, and recreational use are the primary causes of near-shore water quality degradation. A balance of the competing uses is extremely difficult to achieve and is still evolving.

Culture on tidal flats requires access to work areas that may not be accessible by boat. Off Road Vehicles (ORV) traffic over

dunes, coastal banks, tidal flats, and through sensitive resource areas could place endangered species and fragile ecosystems at risk. Use of the intertidal area for bottom culture also raises concern over the potential loss of resting and feeding areas for migratory birds. Some environmentalists see the use of nursery trays, netting, and pens on the flats as developing a "monoculture" that threatens the intertidal ecosystem.

f. Economics

The propagation of shellfish on the tidal flats represents both an alternative to traditional commercial fishing and, some fear, a source of competition with the wild fishery (although the limited data available demonstrate little basis for such concern) for the same market.

The reservation of tidelands for shellfish licensed-areas and aquaculture licenses should not, in theory, limit areas used by commercial fishermen engaged in gathering wild stock. The fear of this in fact happening, exists. The importation of seed from other areas may represent a risk to native populations through disease introduction and gene pool homogeneity. In some areas of the United States where wild stock represents a strong market resource, the political pressure employed to limit aquacultural endeavors is significant; i.e. Alaskan salmon fishery.

The fear of competition has a long history in the Northeast. Within the last century, violence has erupted over the existence and placement of shellfish licensed-areas. Maine, Massachusetts, New York, and Connecticut have all experienced their own versions of the "Quahóg Wars", violent clashes between culturists and commercial fishermen resulting in shootings, boat-burnings, and the seizure and/or destruction of product on both sides of the argument.

The New England states have resolved many of these conflicts in a number of ways. The states of Maine and Connecticut have established procedures designed to limit aquaculture to areas that do not intrude upon the wild fishery. Massachusetts, who has, for the most part, delegated the licensed-area procedure to local authorities, requires that any area proposed for a shellfish licensed-area be a non-productive tideland; a shellfish desert, and some towns have created shellfish management plans that prohibit the siting of licensed-areas in any area where a potential conflict over access to wharves, moorings, or productive bottom may develop. Rhode Island, with its insistence upon a very old and very literal interpretation of the "free and open fishery," has forced most aquacultural activities out of the state.

g. Bottom-Culture -- Problems

The following are both real and perceived problems associated with bottom culture techniques:

History/Culture

Shellfishing, both recreational and commercial, is viewed as a Massachusetts' birthright. The notion of "domesticating" it into what is viewed as a form of rather unaesthetic farming, is not popular; it is inconsistent with the way Massachusetts has traditionally perceived itself and its natural resources.

Financial/Business

Misconceptions exist about bottom culture providing a livelihood or really being a viable business endeavor in Massachusetts, fueled to some extent by the failure on the part of many aquaculturists to conduct their activities in a consistent, businesslike manner. It has been reported to Massachusetts aquaculturists and to various state agencies that coastal aquaculture should not be viewed as a real form of sustainable fishing nor as an industry that justifies or deserves the assistance available to many other small businesses, funded through taxpayer dollars and assisted by state and federal programs and subsidies. The perception exists and persists that the people engaging in bottom culture do it as a hobby, or to pick up a few extra dollars "under the table" or to supplement their "real" jobs. For many serious bottom culturists, this is simply not the case. Given the productivity that can be achieved with a carefully managed licensed-area, bottom culture is engaged in as a serious, full-time occupation.

The nature of the work involved to sustain a profitable licensed-area is not something most people would do to "moonlight." Even those considered part-time aquaculturists typically spend at least a portion of each day on the licensed-areas. For intertidal licensed-areas, all work has to be done on ebb tides, which vary from day-to-day. It means going out to secure the licensed-area in foul weather. During harvest season, it means harvesting every day, no matter what the conditions may be. The work is manual, extremely labor-intensive, and technical assistance and tools are very limited. Immediate responses to emergencies: floods, storms, etc., are necessary if a year to two years' worth of work and investment is going to be saved. Bottom aquaculture is not, nor should it be considered, a hobby.

Although the work and investment risk are substantial, the returns may be significant, as pointed out elsewhere in this report. However, it is acknowledged by nearly everyone involved with coastal aquaculture: shellfish officers, harbor masters,

Division of Marine Fisheries personnel, and several aquaculture trade organizations, that bottom culturists do not, by and large, conduct their operations in a professional manner. Recordkeeping is poor and in most cases, insufficient to establish a clear financial picture. Reporting of harvest quantities and prices received is chronically and severely skewered on the low end; average annual reports, required by M.G.L. c. 130, contain amounts and prices that are just sufficient for a licensed-area-holder to maintain his/her right to the licensed-area. The under-reporting problem is so generally known that the Division of Marine Fisheries assumes that actual quantities of some species of shellfish harvested and prices obtained are as much as 40 - 60% higher than what is reported.

There has traditionally been little public interest or support for programs that encourage aquacultural development over other uses of highly desirable coastal property. Banks and other lending institutions find little justification for creating small business loan packages for aquaculturists. State and federal government agencies are reluctant to devote thin resources to endeavors which do not appear to provide an adequate return for the investment. In addition, the risk of losing the harvest to disease, predation, destruction by storms, algal blooms, theft or other causes leads to a perception that aquaculture is a high-risk investment, causing banks and lending institutions to proceed carefully.

Public Health

Shellfish have, despite public education and awareness campaign efforts by the industry and the state, a mixed reputation for wholesomeness. Shellfish have in some instances been linked with disease transmission to humans, causing many consumers to avoid any form of shellfish. Aquaculture and public health are discussed in greater detail in Chapter Six.

Water Column (or Off-Bottom) Culture -- Overview

The use of water column suspension techniques, including enclosures (cages, lantern nets) and lines (longlines and strings attached to rafts or racks anchored on the bottom) for the production of bottom-dwelling and sedentary shellfish, as well as for motile species of shellfish (i.e. scallops) is commonly referred to as water column or off-bottom culture. These techniques are designed to minimize bottom predators, contain mobile species (i.e.scallops) in one place until harvest, and maximize the use of a three-dimensional space for cultivation.

a. <u>Species Cultured</u>

Oysters have been cultivated at least since Roman times, by growing them off of the bottom on rafts and strings. Today, oysters are grown all over the world, using a variety of methods, predominantly off-bottom. In Japan, one of the largest oyster producers, cultivation methods include rafts, lantern nets, and longlines. In Australia, another large oyster-producer, sticks and trays are used. In France and England, oysters are cultivated on off-bottom posts, in mesh nets, and on longlines. Off-bottom cultivation has uniformly produced (1) more oysters than in the same area on the bottom, (2) accelerated growth rates, (3) improvement in meat quality, and (4) significant reductions in predation.

Two different kinds of oysters are cultured in Massachusetts, using off-bottom and bottom methods: the Eastern, or American oyster, *Crassostrea virginica*, and the European oyster, *Ostrea edulis*. In Massachusetts, there are currently seventy-eight oyster cultivation licensed-areas, representing both bottom and off-bottom culture in seventeen cities and towns (Barnstable, Chatham, Eastham, Edgartown, Essex, Falmouth, Gosnold, Mashpee, Mattapoisett, Nantucket, Orleans, Plymouth, Provincetown, Truro, Wareham, Wellfleet, and Yarmouth).

Mussels are one of the easiest species of shellfish to grow; some varieties can in fact become a nuisance, fowling intake ducts, drains, marine equipment, and boats. One nuisance species, the zebra mussel, *Dreissena polymorpha*, appeared in the Great Lakes region with imports of Asian mussels. This mussel has become so prolific that routine maintenance must be employed to clear intake ducts and sewer pipes that become significantly obstructed by these prodigious breeders.

Although mussel culture is extremely popular in Europe, on the U.S. West Coast, and in Maine, it is limited in Massachusetts. There had been as many as eleven blue mussel cultivators in operation in Massachusetts during the "mussel boom" years of the late 1980's, but there is very little, if any commercial production of mussels today. Recent advances in cleaning and grading wild harvest mussels has resulted in a drop in price for the cultured mussels which had previously been marketed as a superior product (Brooks, 1993).

The blue mussel, *Mytilus edulis*, is simple to culture off-bottom, due to its prodigious reproductive capabilities. The spat is abundant and sets easily on longlines and ropes, precluding the need for hatchery support. Mussel seed in Massachusetts comes entirely from natural populations. Empty mussel strings are placed in the water in June and July (depending upon temperature) to catch seed. Following collection of the seed, the strings may either be left in place or transferred to another growth area. The mussels are grown for 6 - 10 months until reaching harvest size and may

remain on the strings for almost two years until the last of a given set is harvested. It is necessary throughout the culture period to lift the strings periodically to remove fouling organisms and to thin the growing mussels.

Cultured mussels produce a shell that is much thinner and flexible than that of a naturally occurring organism, creating some unique harvest problems. Layers of mussels have to be removed from the lines carefully, to avoid damaging the shellfish. Although no one answer can account for the difference in shell structure, the most popular theory has it that mussels react to intertidal pressures and wave action by growing much more rigid, thicker shells than do those suspended in the water column.

Mussels cultured off-bottom do not experience the predation problems of bottom-dwelling mussels, who are a favorite food for many varieties of starfish. Off-bottom culture has been the target of a commensal organism; the pea crab, who is found to co-exist in the shell of mature, cultured mussels. Cultivators have taken two approaches to the pea crab; it is either marketed as a desirable companion product, or it is destroyed by adding extra carbon dioxide to the water around the culture strings.

The bay scallop, *Argopecten irradians*, differs from the soft clam, the quahog, the oyster, and the mussel in several respects of significance to the aquaculturist. It has more rapid growth, a shorter life-span, and is less likely to transmit disease to human consumers if taken from contaminated areas. It is also harder to adapt to cultivation.

Scallops are subject to attack from several predatory bottom species, notably the starfish and the oyster drill, again making off-bottom techniques the culture of choice for scallops.

b. Techniques

Lantern Culture utilizes a cylindrical container fashioned from nylon netting, divided into sections and hung from floats and is used in Massachusetts to culture bay scallops and oysters. As juveniles metamorphosize and attach themselves to a substrate, they are maintained in a hatchery or other natural environment until they attain approximately 3 millimeters in size. At that point, they are transferred to natural growing areas, equipped with fine mesh nets suspended from rafts on the surface and anchored to the bottom. This method utilizes the three dimensional growing space for continuous feeding and limits predation.

Raft culture utilizes strings suspended from a surface raft which is anchored to the bottom. In many places, suspended culture from rafts or longlines has proven to yield the greatest production per unit area of the possible culture methods. Mussels and oysters

may be cultured in this manner. In Spain, where mussels are grown suspended from rafts, a maximum production of 500 metric tons per hectare (250 tons per acre) has been achieved. This figure is 1,000 times greater than any other form of aquaculture in which animals are grown without supplemental feeding. Currently there are no raft culture operations in Massachusetts.

Rafts may measure up to approximately 30 x 300 feet, with 180 - 270 ft. longlines, The mussel strings are suspended from the rafts and extend about 21 - 30 feet below the surface. Up to 400 strings may be hung from a single raft or longline and the raft can support up to 9 metric tons of mussels.

The term "**rack**" may be used in several ways. Depending upon what is meant by the word, alternative culture methods are available.

A rack for the growing of scallops and oysters is a device constructed from wood, wood and plastic, and/or various hybrids of non-corroding metals and plastics, that resembles a bureau, complete with pull-out drawers, suspended several feet off of the bottom. Seed shellfish are set out in the drawers and allowed to mature in the water column, safe from bottom-crawling predators.

A rack may also be used in concert with longlines and/or string and lantern culture. When used in this way, a rack is nothing more than a hollow square or rectangular frame, resting on the bottom as an anchor to provide stability and separation for the lines or lanterns suspended in the water column.

c. Current Water Column Culture Leases

There are approximately twenty-eight licensed off-bottom aquaculture operations on 226.5 acres of surface water and water column off of fourteen Massachusetts cities and towns (Barnstable, Chatham, Dennis, Eastham, Edgartown, Essex, Fairhaven, Gosnold, Mashpee, Orleans, Plymouth, Provincetown, Wareham, and Yarmouth). Few of these licensees are operational. Cultivated species include American and European oysters, bay scallops, and blue mussels.

d. Legal Issues

The authority to regulate and maintain near shore areas has traditionally been local; harbormasters and shellfish officers routinely allocate mooring space, issue permission for temporary uses, assign public marina slots, and oversee shellfish licensed-areas.

Water column aquaculture requires greater regulatory

involvement than bottom culture generally due to the exclusionary nature of this technique. Off-bottom culture may require a M.G. L. c. 91 waterways license, issued by the Department of Environmental Protection or a Ch. 91 permit issued by the municipal harbormaster, because it uses "navigable" area: the water column and/or the surface, as well as the bottom and may conflict with navigation or other uses. Off-bottom culture also requires a license authorized through M.G.L. c. 130, section 57. Local authorities (selectmen, mayor) issue the section 57 licenses and to some extent, they intrude upon the traditional authority granted to harbormasters to assign moorings and designate areas for scuba diving. Which use takes precedence, how the uses should be distinguished, how the uses may accommodate each other, have the potential for controversy and the procedures employed in the licensing of the various uses are a subject for further legal scrutiny and clarification. Coordination efforts between state and local entities concerning information exchange and reporting requirements also need to be reviewed.

e. Environmental Issues

Off-bottom culture carries with it its own set of demanding water quality requirements, as well as its own effects upon surrounding water, microfauna, macrofauna, phytoplankton, and sediments.

Phytoplankton: Mussels and oysters feed by filtering suspended particulate matter, both plankton and detritus; the biomass of phytoplankton downcurrent of mollusk culture therefore may be expected to be reduced. Mollusks are effective in removing particulate matter. In one study, particulate concentrations were measured after passage through oyster rafts, each supporting 50,000 - 90,000 oysters. The particulate concentration was reduced 76-95% after passage through 11 rafts (although some of this may be attributed to passive settling rather than removal by the oysters.)

There is also anecdotal evidence of the filtering efficiency of mussels. Growers have found that mussels on the upcurrent side of a raft grow faster than those on the downward side, presumably because of the reduction in food concentration as the water passes through the raft. Divers have reported the water clarity in the midst of mussel strings to be substantially improved over conditions beyond the perimeter of the raft, presumably because the mussels have reduced the concentration of suspended particulates.

Waste Loading: Shellfish culture is associated with nutrient-loading, but nutrition is obtained from indigenous phytoplankton and particulate matter, rather than from any external food source. Thus, the culture operation does not introduce any "new" nutrients into the marine environment, but promotes the recycling of those which are already present. There is actually a

net decrease in nutrient levels in the system, since about only 40% of the total nutrients removed by mollusk culture is released directly to the water column; 30% fall to the bottom as particulate material and 30% are removed in the harvest.

Shellfish generate solid waste in the form of feces and pseudofeces. Shells which fall from the culture structure also accumulate on the bottom immediately under the raft or longline. Studies of oyster culture in Japan indicate that the amount of solid waste produced by shellfish culture can be considerable. A raft of oysters in Hiroshima Bay holds 350,000 - 630,000 oysters. During a nine month culture season a single raft will produce 16 metric tons of feces and pseudofeces, with an additional 4.5 tons attributable to feces of fouling organisms growing on the rafts. Approximately 20 - 30% of this material is deposited on the bottom.

f. Economics

As noted earlier, off-bottom culture has the potential to provide some of the highest yield figures for shellfish culture, particularly if some of the other problems associated with the growth of the off-bottom industry can be adequately resolved. The actual dollars generated by off-bottom culture are not precise; current figures do not distinguish between culture practices and many figures do not distinguish between cultured product and wild stock.

Most of the traditional oyster grounds in Massachusetts have now either been closed due to pollution or have been harvested to the point of extinction. Significant natural sets still occur in some of the salt ponds on Martha's Vineyard and in the Towns of Wellfleet and Wareham, but much of the current production is aquaculturally-derived, utilizing both naturally produced and hatchery seed. The most favorable growing areas and licensed-areas are found in the waters around lower Cape Cod; virtually no oysters are harvested north of Cape Cod.

Catch statistics from 1889 to the present indicate that oyster production in Massachusetts has steadily declined since the turn of the century. Production fell during the 1950s and has remained relatively constant since that time. The sharp decline in the 1950s occurred during a period of set failures in Long Island Sound that prevented Massachusetts growers from obtaining seed. The brief resurgence in the industry in the 1980s resulted from the increase in the availability of seed from Connecticut in the 1970's.

The importation of seed had to be discontinued in the mid-1980's after the identification of the oyster pathogen - Haplosporidium nelsoni, commonly known as MSX Disease, among the

imported oysters. Recently, oysters selectively bred for resistance to MSX at Rutgers University have shown encouraging results and offer considerable hope to the industry. More recently, however, oyster growers have suffered heavy losses among juvenile oysters from a cause other than MSX, presumed to be a pathogen, but as yet unidentified. These recent mortalities, which produced heavy losses in 1990-1991, occurred among hatchery-reared seed in Massachusetts, New York, Rhode Island, and Connecticut.

Reported total landings on Cape Cod in 1989 were approximately 7,000 bushels, of which more than half were cultured on private growing grounds. In 1990, the wholesale price for oysters was slightly over $10.00 per pound (shucked), or more than twice that for quahogs.

Massachusetts has always been a major producer of bay scallops, although predominantly from the harvest of wild, rather than cultured, stock. This species rarely occurs in commercial quantities north of Cape Cod, exceptions being Plymouth and Duxbury Bays, but the comparatively warm water of the numerous and shallow coves and salt ponds of southern Massachusetts have provided an ideal habitat in the past. For many coastal communities, the bay scallop fishery has produced a steady source of income and has been an important contribution to the economy during the winter.

The price for bay scallops varies greatly from year to year, varying indirectly with abundance. In 1990, which was a lean year, the ex-vessel price was $6.61 per pound of shucked meats. In more productive years, the price may be considerably less. A consistent characteristic of the bay scallop fishery has been fluctuations in abundance from year to year, with relatively productive years often immediately followed by general scarcity. The annual bay scallop harvests in Massachusetts near the turn of the century were not much larger than in good years today. However, during the 1970s and 1980s, bay scallops virtually disappeared from many areas in which they were quite abundant, and good years occurred infrequently. It is suspected that the disappearance of the bay scallop in some areas may be linked to increasing boat traffic, as larger amounts of hydrocarbons - a toxin to this species - are released into the water. Other pollutants have undoubtedly contributed to this decline.

In the past, only the adductor muscle of the bay scallop has been marketed for consumption. Pathogens do not accumulate in the adductor muscle. Therefore, scallops may be taken from areas closed to the harvest of other bivalves if only the adductor muscle is to be marketed. However, increases in whole and roe-on scallop consumption has increased, and these scallops must come from approved areas. The legal proscriptions against the harvesting of scallops less than one year old has provided a practical means for protecting the natural stock. Bay scallops, however, are highly

sensitive - particularly in the embryonic and larval stages - to a variety of chemicals frequently associated with industrial and domestic wastes and the adults cannot survive in areas of heavy siltation or reduced oxygen conditions.

Although the bay scallop is readily cultured through its early development in hatcheries, to date it has proven impractical to rear to maturity in large numbers in the wild due to its mobility, as well as its vulnerability to predators. This is where aquacultural techniques such as lantern nets have the potential to become so valuable.

g. Off-bottom Culture -- Problems

The following are problems, both real and perceived which are associated with Off-Bottom Culture.

Historic/Cultural

Water column culture suffers from the same lack of common understanding afflicting bottom culture. The cultural identity of Massachusetts in its wild shellfish industry is at odds with the notion of a domestic shellfishery, particularly one that intrudes upon traditional shore and near-shore activities. Off-bottom culture also intrudes upon the water surface and near-shore bottom, affecting mooring availability, recreational boating and navigation.

Use Conflicts

Due the exclusionary nature of this aquaculture technique, other activities (including navigation) in the area of a water column aquaculture facility are displaced. Siting of these facilities is therefore subject to considerable controversy from other users.

b. **Technique**

A fish farm operation consists of distinct components and support arrangements. In addition to the enclosures themselves, boats, ramps, handling equipment, on-and off-loading equipment, and hatchery and/or fry-holding facilities are necessary.

Salmonid farms hold the fish in net enclosures, pens or cages. The actual dimensions of the enclosures will vary depending upon density of the fish, size to be attained, water circulation, etc. Typical enclosures average from 8 x 10 to 12 x 12 meters square, with an average depth of two - four meters. Sufficient clearance must be allowed below the enclosure to provide adequate circulation for the distribution of wastes and nutrients. In most fish farms, the enclosures are strung together to form a single, large unit, separated by handling areas or walkways.

Eggs are hatched and fry are obtained from fresh water hatcheries for salmonids. Although salmon are anadromous, farm-bred fish do not exhibit this characteristic behavior. Salmon smolts are generally transferred to net pens off-shore in the spring, where they are held until reaching harvest size. Harvest size will vary depending on the market, the demand, and the regulatory climate. For example, fish meant for the "pan-sized" market would be held until they weighed 0.3 - 0.5 kgs.

c. **Legal Issues**

The only instance of a request for permission to operate an offshore (in federal waters) fish farm in Massachusetts occurred in 1988 (Norwegian American Fish Farms, Inc.). The proposal described ninety floating enclosures, the largest facility to be sited on the East Coast and a near-shore smolt facility off of Rockport. Insufficient environmental, economic, and engineering information was available to proceed with reviewing the project and the proposal is still on the drawing board. The initial review of this proposal illustrated the extent and complexity of legal requirements, as well as the need to create a more manageable structure for siting and permitting fish farms if they are to become economically viable in Massachusetts.

The proposed fish farm was required to submit permit applications to the U.S. Army Corps of Engineers for ocean discharge and dredge and fill permits. The United States Environmental Protection Agency needed to review and approve an application for a Clean Water Act NPDES permit. The Department of Defense had to issue a waiver on the site as a "non-security" area. For any component of the proposed facility to be sited in state waters, the environmental agencies of the Commonwealth of Massachusetts had to review a coastal finfish aquaculture permit application, a state clean water act permit application, and a

CHAPTER TWO - FISH FARMS & OTHER TYPES OF AQUACULTURE

FISH FARMS

The rearing of finfish in floating structures: net pens, cages, or enclosures, is developing rapidly on both coasts in response to greater demand for a quality, cultured product and diminishing wild fisheries.

Fish farms are not to be confused with ocean ranches. Ocean ranching is the practice of releasing cultured salmon from a designated location into the wild, with the expectation that the salmon will return to the point of release in sufficient numbers to create an economically viable enterprise. There are no ocean ranches presently operating on the east coast of the United States, although the practice is prevalent in the Pacific Northwest and Canada.

The fish farm industry is also more advanced in the Pacific Northwest than it is on the East Coast. The fish farm has been an established fisheries alternative in the Puget Sound area since the 1960s and is continuing to expand. In 1991, Puget Sound fish farms produced approximately 1,500 metric tons of salmonids, primarily coho (Onchorhynchus kisutch), chinook (Onchorhynchus tshawytscha), and Atlantic (Salmo salar) salmon.

The only fish farms located in New England are in Maine, where concerted efforts have been made to encourage their development and establish a streamlined, but strict regulatory climate. Currently, there are thirty-six fish farm leases in Maine; in Damariscotta, Bristol, Bar Harbor, Freeport, and Kittery. The leases represent approximately two square miles (out of Maine's 2,000 square mile coast). The predominant species reared is Atlantic salmon. Finfish farms have been proposed in Massachusetts offshore of the north shore, in Cape Cod Bay and south of Martha's Vineyard.

a. Potential Species to be Cultured

There are presently no fish farms is Massachusetts. The following species have been proposed for farming in the state.

Atlantic Salmon (*Salmo salar*)
Atlantic Cod (*Gadus morhua*)
Steelhead Trout (*Oncorhynchus mykiss*)
Summer Flounder/fluke - (*Paralichthys dentantus*)
Winter Flounder - (*Psuedopleuronectes americanus*)
Bluefin Tuna - (*Thunnus thynnus*)

variety of commercial fishing, brokering, storage, transfer, and sale licenses. Much of the required information was overlapping and redundant. To date, the fish farm is still only a proposal.

In addition to the above requirements, a Chapter 91 lease (or permit) may be required for leasing state submerged lands. No such leases have yet been executed for aquaculture facilities. Bottom culture has thus far been waived from the necessity of applying for a Chapter 91 lease, because it is not an exclusive use of submerged land. Off-bottom culture and fish farms are more exclusive uses and therefore, may require a Chapter 91 lease. Approval by New England Fishery Management Council may be necessary for any aquaculture facilities located in federal waters (outside of three miles). Additionally, a consistency determination from the Coastal Zone Management office would be required of any project receiving a federal permit (ACOE, NEFMC). More detail on regulatory requirements can be found in the Legal chapter of this paper.

This scenario of regulatory complexity is the same everywhere. Maine has created a separate regulatory structure for the encouragement and development of fish farms, distinct from the wild fishery. The Maine system establishes a "one-stop shopping" office for aquaculture generally, with varying requirements depending upon the size of the operation and the anticipated impact. Under the jurisdiction of the Department of Marine Resources, Office of Aquaculture, the environmental, engineering, financial, and technical information necessary to demonstrate permit compliance for the State of Maine and for the federal government is submitted and reviewed. This information is shared among the relevant agencies and after agency review is concluded, a public hearing is conducted on the feasibility of granting the aquaculture lease and the conditions attendant to it. See Appendix, Aquaculture Laws of Connecticut, Rhode Island, and Maine.

d. **Environmental Issues**

Perhaps the most controversial aspects of any analysis of fish farms are the myriad of environmental-impact questions raised. Fish farms influence and are influenced by a very complex set of natural and manipulated forces, including water velocities, water depths, wind and wave action, dissolved oxygen, temperature, salinity, and pollution. The most significant environmental changes addressed (and the changes most likely to create dissension, opposition to the industry, and regulatory chaos) can be summarized as follows:

Sedimentation/Organic Loading

Fish farms generate large amounts of solid wastes in the form of feces and unutilized feed. These materials are generally deposited in the immediate vicinity of the culture structure. This deposition can result in physical and chemical changes to the

natural sediments including decreased redox potential, increased sediment oxygen consumption, and increased concentrations of total volatile solids, total organic carbon, sulfides, nitrogenous compounds and phosphates. While there are profound effects on sediment chemistry and consequently the sediment biota, these effects appear to be localized. Visible accumulation of solids and the alteration of sediment chemistry typically extends no more than 30 meters from the culture structure and benthic community changes observed have been limited to the same thirty meters. Sediment accumulation may be expected to occur beneath any culture facility when less than 15 meters exists between the bottom of the structure and the sea floor. Sediment accumulation is possible at even greater depths, but little data is available since few culture operations have been sited in deeper waters.

The accumulation of organic-rich sediments beneath culture facilities and the consequent depletion of oxygen in the sediment pore waters results in changes in the infaunal invertebrate community. Loss of species intolerant of organic enrichment (typically echinoderms, crustaceans, and mollusks) often occurs. Opportunistic species like polychaete worms may move in and attain numerical dominance in the community. In cases of extreme organic enrichment, there may be a total absence of benthic macroinvertebrates. These changes can be expected to persist for the duration of culture activities and for at least several years following their cessation.

Accumulation of organic material in the vicinity of a fish farm may result in the loss of nonmotile megafauna (i.e. surfclams) living in intimate contact with the sediments. However, fish and motile megafauna (e.g. crabs) living on or above the sediment surface are typically found in higher densities around fish farms than in the surrounding area. The attraction of fish and megafauna to the culture area is probably due to increased availability of food in the form of feed unutilized by the cultured fish, the high abundances of opportunistic macroinvertebrates, and the epifaunal organisms living on the culture structure or which fall to the bottom.

Water Circulation

Fish farms may change water circulation and water-quality. The likelihood of these effects and their potential magnitude is highly dependent upon site-specific conditions or the species cultured. A fish farm placed in the marine environment may reduce current velocity in the surrounding area, particularly in the down current direction. This reduction in current velocity will impair dilution and dispersal of wastes downstream of the farm. However, this effect is not likely to be significant except in cases of intensive culturing in an area with very restricted natural circulation.

Water quality

Cultured organisms and culture practices alter the chemistry of the water passing through the fish farm, most notably increasing ammonia concentrations and decreasing dissolved oxygen concentrations. The concentration of nutrients and BOD in the water passing through fish farms are generally very dilute compared to most other discharges to the marine environment.

Phytoplankton

There are no good available data quantifying phytoplankton changes in the Gulf of Maine as the result of the existence of the thirty-six currently operating fish farms. As many local species are not limited by the addition of nutrients, it is not likely that measurable effects will be imminently detected. Nutrients may periodically be limited in vertically stratified areas and in poorly flushed embayments.

Exotic species

The importation by fish farms of live stock into the state may represent a threat to wild species. Introduced species may establish self-sustaining wild populations, potentially becoming pests or eliminating native species. Future import requests should be carefully evaluated for this potential.

Toxics and Disease

There are several issues for which available data are inadequate for a conclusive determination of significance. These include (1) the environmental and public health effects of antibiotic usage; (2) alteration of the wild gene pool; (3) the capacity for a fish farm to serve as a disease reservoir for the infection of wild organisms; and (4) the proliferation of human pathogens in the vicinity of fish farms.

Concerns over the introduction of disease through fish farms have long been expressed. Thus far, little evidence has been developed to demonstrate that cultured fish serve as a reservoir for disease affecting wild fish. The general outbreak of a species-wide disease is usually associated with some form of stress. Within the culture environment, fish may be stressed by overcrowding, undernourishment, poor water quality, and physical damage associated with handling and confinement. While cultured fish may demonstrate more frequent appearances of disease than wild fish, disease does not appear to be transmitted to the wild population generally.

Although salmonid bacterial diseases are not transmissible to human consumers, there has been some question raised about whether

the organic enrichment of bottom sediments caused by fish farms could promote the growth of those species pathogenic to humans. Consumption of shellfish collected in the vicinity of a mariculture operation could then serve as a vector for human infection. This is an issue where available scientific evidence is very meager, but experience to date has failed to demonstrate cause for concern. Increased bacterial abundance in sediments beneath fish farms is probable, but it has not been demonstrated that this increased abundance is of any significance in terms of human health.

Genetic Effects

The issue of the genetic effects of fish farms is still somewhat speculative. Cultured organisms may be at a competitive disadvantage with respect to wild stock. If escapes and interbreeding occur, there could be some temporary loss of reproductive capacity in the wild population resulting from the production of less-fit genotypes. The potential magnitude of this effect is dependent upon the proportion of the breeding population comprised of escaped animals. It should be noted, however, that for years fisheries managers have routinely transferred hatchery-reared salmonids between river systems to improve commercial fisheries. Outside of a natural disaster, such as an unexpected violent surge, the number of fish potentially escaping from fish farms, by comparison, is minimal.

Drugs

Fish farms require the use of drugs; antibiotics, hormones, vitamins, parasiticides and fungicides. The potential environmental effects have not been adequately quantified. However, the greater the use of highly water-soluble drugs (i.e. oxytetracycline), the less impact there is anticipated on surrounding waters. At this point in pharmaceutical development, no difficulties have been reported.

Structural Integrity

The structural integrity of fish farm structures and the damage that broken structures could cause on adjacent shoreline facilities is an issue which must be considered when evaluating the effects of offshore fish farms. Since most offshore sites in Massachusetts are very exposed to storms, the possibility of facility break-up is real.

e. **Economics**

Although fish farms represent a potential for tremendous productivity and economy of scale, traditional fishermen are very suspicious of them and many objections have been raised about encouraging their development.

Fish farms occupy a three-dimensional space; the surface, water column, and bottom. This use effectively forecloses the area of the water column and the bottom from certain other uses; i.e. lobstering, and has been the basis for continuous objection to the siting of fish farms. Currently, this is not a realistic concern. There are no leases in Massachusetts and the leases that exist in Maine obstruct insignificant amounts of the bottom and the water column, relative to their productivity. The Maine Department of Marine Resources (DMR) and the Maine State Planning Office report that, in 1992, lobster production was valued at fifty million dollars, while farmed Atlantic salmon were valued at eighty-eight million dollars. There is no current, reliable data available to conclude one way or the other whether fish farming depresses lobster take. Maine DMR believes that there is no relation, as fish farms in Maine do not remove significant amounts of productive lobster bottom. Conflicting uses, including lobstering are considered by DMR when making lease determinations.

The next objection has effectively foreclosed fish farms in some areas; pressure from commercial wild fishermen who do not want to compete with cultivated stock for the same market. In Alaska, where the wild fishery is an extremely potent legislative force, fish farms are proscribed.

Scientific uncertainty about the impacts of fish farms on other species, benthic populations, water quality, wind and wave action, disease, and predation, raise a series of questions about indirect costs of fish farms, with few good answers at this point. In Maine, there has not been any reported negative impact on the wild fishery, despite considerable monitoring.

The prospects for this industry however, are clear. World demand is consistently outstripping supplies of finfish and states (i.e. Florida, Virginia, California) in which efforts have been made to encourage the industry are demonstrating economic success. Maine produced 11,000 metric tons of cultured salmon in 1992 and 360 full-time jobs in the fishery.

f. **Problems Associated with Fish Farming**

The concerns raised about fish farms are similar to those encountered when feedlot management is proposed: pollution, disease, overcrowding, competing uses/abuses and degradation of

resources. Navigation problems further complicate the siting of fish farms.

Because fish farms are an exclusive use of submerged lands and also because they are perceived as having the potential of causing environmental degradation, siting fish farms is generally very controversial. Siting problems occur both because other users want to use the same area slated for fish farm development and because shore side landowners and sometimes, communities oppose the locations of fish farms from an aesthetic perspective. The aesthetic argument has prevailed in some areas of Washington State where aquaculture has basically been shut out by the viewpoint that pristine views are more important (for tourism and lifestyle) than is aquaculture. On the other hand, the argument that aquaculture is a priority use of submerged lands, a means of diversifying the economy in coastal areas and increasing the availability of fresh seafood has resulted in the successful siting of fish farms in several areas of the country.

SEAWEED

Seaweed is an important food source in the Far East and portions of Africa; several varieties of seaweed are cultivated as vegetables, among them *Porphyra*, *Ulva lactuca*, *Chondrus crispus*, and *Eucheuma*. Its use in the United States, until very recently, has been limited to phycocolloids, the gelatin-like substance extracted from seaweed that is used as a food and drug additive. The phycocolloids are extracted for use as emulsifying, binding, and smoothing agents in foods and drugs. The primary phycocolloids are carrageenan, agar, and alginate and are commonly found in ice cream, pudding, and toothpaste. Carrageenan is being studied because of its ability to slow, and in some instances, to halt the progress of the AIDS virus. Researchers have found that carrageenan inhibits the genetic replication of the AIDS virus and prevents infected cells from fusing together.

Research into seaweed culture and uses of seaweeds on the east coast is being conducted at the State University of New York at Stony Brook, the University of Maine at Orono, and the University of Connecticut.

a. Species Cultured in Massachusetts

Although no commercial seaweed culture currently exists in Massachusetts' territorial waters, experimentation and demonstration projects do exist, researching seaweed aquaculture both as a stand-alone operation and as a polyculture with fishfarms. The potential exists for production of an economically

viable product that utilizes the by-products of fish farm culture.

There is one commercial seaweed farm operating in Maine today that is experimenting with growing two forms of edible seaweeds that use nitrogen- and phosphorus-bearing waste (components of fish wastes) as their food source. The project has not been operating long enough to develop dependable datasets, but the early monitoring results are promising.

The seaweed farm, operating in Passamaquoddy Bay, Eastport, Maine, is culturing two Japanese species of edible seaweed; Porphyra yezoensis and Porphyra nori. The operation grows and distributes its own product and sells pre-seeded nets to other entrepreneurs. Interest in growing seaweed along the east coast is high and many small demonstration projects are being developed by researchers and aquaculturists (the University of Massachusetts at Boston, the University of Maine and the Maine Aquaculture Innovation Center are all experimenting with seaweed culture).

b. **Procedure**

The culture process is different and less labor-intensive than fish farming. The seaweed growing apparatus, consisting of 60' by 5' nets stretched across PVC frames, are set out in mid-May in Maine and removed by December. Scallop shells are "seeded" with seaweed spores and spread on the sea bottom. The nets are then placed over the shells, to allow the spores to seed onto the nets. Once seeded, the nets are brought to just below the surface of the water and the seaweed grows, primarily by digesting nutrients from the surrounding water.

For the first three weeks after seeding, the nets are raised above the water surface daily to dry. The drying process does not affect the cultured species, but effectively destroys microscopic diatoms that attach and compete with the cultured seaweed. After the first three weeks, the drying process is no longer necessary; the porphyra will have grown large enough to resist diatom intrusion. The first crop takes approximately six weeks to mature and subsequently, for the next four - six weeks, can be harvested weekly.

c. **Problems Associated with Seaweed Culture**

Limited markets presently exist for seaweed products on the East Coast. Although the demand for fresh nori and other types of edible seaweed is significant in Japan, quality control, shipping problems and most importantly, trade restrictions, hamper East Coast production. The edible seaweed market in the United States

is currently worth approximately thirty million dollars annually. Although the Japanese market, estimated to be worth 1.5 billion dollars annually, is closed to foreign imports, edible seaweed is one of the products currently being negotiated by the United States Trade Representative.

d. **Economic Issues**

The economic advantages of polyculture (combining fish farming and seaweed culture) are clear. Currently, Maine salmon farmers use between 20 - 30% of their total lease area for actual fish culture; seaweed culture could be employed in the fallow areas without obstructing the fish farm operations and maintenance. The seaweed would utilize some of the by-products of the fish culture and the necessary state and federal permits (Maine Dept. of Marine Resources Aquaculture Leases, approvals from the Coast Guard and the United States Army Corps of Engineers for siting, federal NPDES permits) could be obtained contemporaneously, with the submission of similar information for both operations. Additionally, the costs of lease payments, permit fees and marine monitoring could be offset to some extent if polyculture becomes viable.

AMERICAN LOBSTERS (*Homarus americanus*)

Cultivated lobsters represent one of the most theoretically profitable aquaculture species for Massachusetts. At present, only two commercial lobster culturing facilities exist; one in Monterey, CA and one on Prince Edward Island, Canada. The Massachusetts Division of Marine Fisheries operates a lobster hatchery in Vineyard Haven, Martha's Vineyard for research and enhancement of the natural fishery.

Lobsters have the requisite characteristics to produce a marketable and very profitable commodity; species' toughness for this area, a demand that always exceeds the supply, a (potentially) diminishing wild fishery, a market price that maintains itself at dependably high levels, and little domestic or foreign competition. The primary obstacles to turning lobster aquaculture into an economic realty are the costs of culture and the length of time it takes a lobster to achieve market size.

a. **Procedure**

The Massachusetts State Lobster Hatchery was established in 1949, pursuant to a mandate of the Legislature for a facility designed to promote research into the biology of *Homarus americanus* and to maintain and enhance Massachusetts wild stock.

The hatchery operates two programs; a research and development facility and a hatchery and stocking program. Between May and August, egg-bearing female lobsters ("eggers") are collected by the Division of Marine Fisheries and commercial fishermen and brought to the hatchery, producing an average of 3,500 eggs/year. The eggs hatch out as first stage larvae, which are free-swimming, cannibalistic, and about the size of a mosquito.

The larvae are held at the hatchery for three molts, until they become fourth stage larvae. At fourth stage, rather than remaining in the water column and on the surface, the juveniles gravitate to the bottom and begin developing legs and claws, freeing them from surface predation and allowing their diet to expand to include hard food sources. This first-to-fourth-stage molting period is a critical period in lobster development; DMF biologists estimate that less than 1/10 of 1% of the young lobsters who hatch initially survive in the natural environment through the fourth molt stage. Hatchery survival rates are much higher, up to 75%.

The reasons for such high juvenile mortality arise from the external environment. First-through-fourth-molt lobster larvae are free-swimming with marine plankton in the water column and on the surface. They are subject to predation pressure from a variety of other organisms and are very vulnerable to toxics in their environment, particularly hydrocarbons produced by boats.

b. Problems Associated with Lobster Culture

Lobsters are cannibalistic from hatch-out and will freely feed on each other, creating unique culture problems. In the hatchery, predation is controlled and the juveniles are discouraged from cannibalism by being kept physically separated (through the use of continuous bottom injection of water to keep the lobsters apart in the water column) and by being extremely well-fed. The costs associated with maintaining physical separation and the diet requirements are, along with length of time to reach maturity, the factors that have kept lobster aquaculture from being a profitable endeavor.

The technical problems associated with lobster culture; physical separation, diet, and maturation times, currently prevent lobster culture from being a viable economic possibility for Massachusetts aquaculture.

c. Economic Issues

The average lobster catch over the past five years (1987 - 1992) has exceeded 14.9 million pounds, at a landing value of over 44.6 million dollars (DMF). Lobsters exceed the value of any other fish or shellfish caught in Massachusetts.

A lobster reaches sexual maturity and approximately one pound in weight in seven years in Massachusetts. Research is being conducted to accelerate growth rates and to breed for larger size and quicker development. It has been observed at the DMF hatchery that lobsters maintained in 70 degree F. temperatures all year long take between five and seven years to mature. At this temperature, diet demands increase. Further research is necessary to develop an economically viable food source for lobster culture. Selective breeding is also being conducted to maximize the edible portions of the lobster. For example, it has been observed that lobsters fed hard shell food earlier into their life cycle develop two larger "crusher"claws, rather than the typical crusher claw and smaller, "ripper" claw.

OTHER POTENTIAL SPECIES

Sea Urchin Roe (*Strongylocentrotus droebachiensis*) - The sea urchin roe fishery in Maine has been very lucrative in recent years and there is a small scale wild urchin fishery in Massachusetts. The huge demand for urchin roe comes primarily from Japan. Many believe that aquaculture holds great potential for urchin culture. Northeastern University receieved a Fisheries Industry Grant (FIG) in late 1994 to experiment with urchin culture at the Nahant Marine Lab.

Soft Shell Clams (*Mya arenaria*) - Although the market price for soft shell clams is not as high as that for other bivalves, there is increasing interest and technological advancement in the culture of this species.

Atlantic clams/surfclams (*Spisula solidissimia*) - Surfclam culture is being experimented with in Maine, CT. and Cape Cod using hatchery seed and hard clam growout technology.

Tautog (cunner) (*Tautoga onitis*) - Tautoug is a native groundfish with white meat which commonly occurs in rocky nearshore waters. Although not cultured commercially at this time, tautog experimentation is occurring at the research level on the Cape.

Striped Bass (*Morone saxatilis*), Haddock (*Gadus morhua*), Sea Scallops (*Placopecten magellanicus*), Wolffish and Halibut are all being cultured in the laboratory in the region and some are beginning to be cultured commercially.

CHAPTER THREE - SUPPORT SYSTEMS

Hatcheries can be and are used to some degree in Massachusetts to supplement production of fish and shellfish both in the natural environment and for use in aquaculture facilities. Relaying and depuration are two different approaches used in the state for cleansing contaminated shellfish. Neither are presently used for aquacultured shellfish although the possibility exists that they could be.

HATCHERIES

There are several hatcheries in Massachusetts devoted to shellfish production. Although individual variations in diet or equipment may occur, the basic operations are similar.

In the typical hatchery, adult shellfish, selected for broodstock on the basis of desirable attributes such as rapid growth and disease resistance, are conditioned to spawn by being held in trays of circulating seawater at temperatures that stimulate the development of eggs and sperm. During the conditioning period, food in the form of microscopic unicellular algae is added to the seawater. The algal food may consist of several different species that are of proven nutritional value to bivalves and that are maintained in cultures in the hatchery facility.

After the conditioning process, which may last some weeks, the adults are induced to spawn, usually by exposing them to a rapid temperature increase and, if necessary, by adding a suspension of sperm to the holding trays. Eggs that are discharged are collected and thoroughly mixed with sperm to insure fertilization. The fertilized eggs are then transferred to tanks filled with seawater that has been filtered to remove possible predators. The temperature of the water in the larval containers is maintained between 25 - 30 degrees C. The larval density usually ranges from 1,000 to 10,000 per liter (approximately 4,000 - 40,000/gallon of water).

Although hatcheries may vary somewhat in their larval-rearing routine, it is the usual practice to change the water in the larval tanks several times each week. This is accomplished by draining the water from the tanks through fine mesh screens that retain the larvae. The tanks are then cleaned and refilled with warm, filtered seawater to which algal food has been added, and the larvae are returned to the tanks. The duration of the larval period in most hatcheries is between one and two weeks. These

methods have been successfully applied to hard clam and oyster larvae in Massachusetts.

Many culturists do not go through the hatchery procedure for oyster seed production; in some areas culturists may rely completely on natural production. For example, on Long Island, NY, areas of natural bottom are dredged to remove oyster predators. Oyster shell is then spread on the bottom during the spawning period to collect seed. After a year of growing in the setting beds, the young oysters are moved to more favorable growing areas, where they grow to maturity. This rather traditional system has worked when conditions are favorable for natural reproduction and when disease and predation can be controlled. In many areas of New England, natural reproduction is too erratic or negligible to provide a reliable basis for culture, making hatchery production an economic necessity.

Aquaculture Research Corp. in Dennis is the state's only commercial shellfish hatchery and produces clam spat for virtually all of Massachusetts' producers.

The Martha's Vineyard Shellfish Group. Five towns on Martha's Vineyard have a cooperative aquaculture agreement for the operation of a non-profit shellfish hatchery which produces seed quahogs, scallops, and oyster spat for distribution to the five Vineyard towns, the Martha's Vineyard Shellfish Group (MVSG). The solar hatchery provides the towns with shellfish seed and uses joint resources for research into improving methods of shellfish propagation. The hatchery has developed its own, genetically-tagged scallops in order to track survival, interbreeding, and population distributions when introduced into the wild shellfish communities. The project also runs public education programs on shellfish enhancement and culture, as well as pollution-abatement programs. The MVSG relies upon support from the state, Dukes County, the towns of Edgartown, Tisbury, Chilmark, Oak Bluffs, and Gay Head, private donations, and the expertise of the local shellfish constables, private aquaculturists, and research facilities at Woods Hole.

The Nantucket Research and Education Foundation is a pilot project for aquaculture training. The program is designed to expand the Town's economic base by enhancing wild shellfish populations through the grow-out of cultured seed and to train fishermen in hatchery techniques, water quality testing and monitoring, and shellfish aquaculture methods.

The Foundation supplies the Town with quahog seed, oyster spat, and eyed larvae and runs a training course in shellfish aquaculture, currently the only one in Massachusetts.

SHELLFISH RELAYING

Massachusetts, along with most other states with shellfish resources, has vast shellfish beds that cannot be utilized because of contamination. As a result, the practice of relaying: moving contaminated shellfish from restricted areas to clean areas and allowing sufficient time for the shellfish to purge pathogens is monitored by the Massachusetts Division of Marine Fisheries. Shellfish are collected under DMF supervision and re-planted for at least one spawning season (June 15 - September 15). Relaying requirements vary from state to state but must be done according to National Shellfish Sanitation Program guidelines.

Relaying provides several benefits. It allows for the utilization of an otherwise unavailable resource; it works over (cultivates) existing natural beds, usually of benefit to the substrate; it further distributes a local gene pool and may provide some natural spawning enhancement. The most significant benefit may be the depletion of natural stock from polluted areas, which reduces the incentive for illegal harvests. Illegal harvests of contaminated shellfish pose a significant public health hazard.

Relaying is not cheap; careful oversight, testing, and monitoring is required. However, in Massachusetts, it has generally been found that the retail value of relayed shellfish, coupled with the unmet production demands, offsets the costs of relaying.

In Massachusetts relaying has been restricted to municipal propagation and enhancement programs and is generally not regarded as aquaculture. The use of moderately contaminated areas as nurseries and a source of seed for aquaculture has been under consideration for some time, but contaminated shellfish are considered to be a public resource. The relaying of moderately contaminated shellfish from other states has been allowed in the past, but is not presently common. In these circumstances stock must be held for at least 30 days before harvest.

DEPURATION FACILITIES

Depuration is the term applied to the purification of shellfish, harvested from moderately contaminated areas, under controlled conditions. The process generally involves holding the shellfish in tanks of flowing seawater for periods of forty-eight to seventy-two hours. The seawater used is sterilized by ultraviolet light. Shellfish harvested from moderately contaminated areas normally purge themselves of bacterial contaminants within forty-eight hours, but may be held for up to 72 hrs. in some circumstances, after which a decline in quality and shelf life may occur.

Philosophic and practical conflicts surround depuration activities. Like relaying (removing shellfish from moderately contaminated areas and re-planting them in clean substrate), depuration provides the means for utilizing an otherwise unavailable resource. It also represents a way of assuring consumers of a clean and safe product. Depuration is practiced globally: England, France, Spain, and Australia have successfully used it for years with a variety of species. Massachusetts has practiced depuration techniques for over sixty years.

Depuration has been resisted on several fronts. Commercial fishermen fear a loss of economic control over the product. Scientists have retained certain reservations about the process. It has been discovered in soft clams that, if harvested from severely polluted areas; i.e. fecal coliform counts in excess of 88 per 1000 ml, a percentage of the shellfish will fail to purge themselves within the forty-eight to seventy-two hour period. It has also been found that some shellfish, particularly if damaged during harvest, may not siphon during the depuration period at all. Finally, even if the shellfish can be purged of most of the bacteria contained in their gut, they may not be able to release viruses in their tissues. A public policy concern relating to depuration is that the acceptance of depuration by a state may discourage solving the pollution problems which lead to shellfish bed closures.

Although several eastern states have authorized the operation of depuration facilities by private sector entities (i.e. Virginia and Maine) Massachusetts has no private depuration capacity. The Department of Fisheries, Wildlife, and Environmental Law Enforcement, Division of Marine Fisheries, operates a shellfish depuration facility for soft shelled clams at Plum Island, in Newburyport.

The Massachusetts Plum Island facility is the only depuration operation in the Massachusetts/Rhode Island/New Hampshire area. Only clams harvested from moderately contaminated areas, i.e. with fecal coliform counts ranging between 14 and 88 per 100 ml, are accepted for processing. Any clams brought to the plant by fishermen and found to have fecal coliform concentrations in excess of 1600 per 100 grams of meat prior to treatment are not considered acceptable and are confiscated. This is because many clams having such high initial bacteria counts may fail to purify within the prescribed time period. Clams qualifying for treatment are held in seawater sterilized by ultraviolet light for 24 hours and are again analyzed. Those with fecal coliform concentrations no greater than 500/100 gram sample after the initial 24 hour period may be released for market without further testing after an additional 24 hours of purification. If the initial 24 hour test indicates concentrations higher than 500/100 grams, additional samples from this group are analyzed again after 24 hours. By the end of the

total 48 hour treatment, the counts must be less than 230/100 grams. If they are not, the shellfish are retained for further sampling or confiscation. The ultimate objective is to meet the National Shellfish Sanitation Program standard of median concentrations of 50 fecal coliforms/100 grams within a 48 hour period, with no more than 10% of the samples exceeding 130/100 grams.

The Plum Island facility operates year-round and currently processes approximately 50,000 bushels of clams during the year. During its sixty year history, there has been no record of any illness that could be attributed to clams processed at the facility. Shellfish which are depurated at the Plum Island facility are tagged as safe for consumption so as to "certify" their cleanliness for marketing purposes.

Depuration has not proved successful in purging shellfish of heavy metals. Although scientific literature suggests that metal depuration is possible, the mechanics of that process have not been adequately addressed. Metal depuration rates vary widely, showing diverse ranges for the same metal within different bivalve species and for different metals within the same species. Laboratory studies have demonstrated that depuration of quahogs of heavy metals was insignificant.

Depuration is not presently used by aquaculturists in Massachusetts but could be under different scenarios. For example, if a shellfish grow-out area became contaminated prior to harvest, an aquaculturist could feasibly bring his harvest to a depuration plant or relay them for cleansing rather than dumping them.

CHAPTER FOUR - WATER QUALITY

The successful growth, propagation and harvest of aquatic animals, whether freshwater or marine, is heavily dependent upon the quality of the surrounding water. The presence of toxic chemicals (i.e. metals, petroleum products, etc.), overloading of nutrients (i.e. untreated, partially treated sewage, point source discharges, non-point source discharges, atmospheric deposition (i.e. lead from internal combustion exhaust, acid rain) artificial or uncontrolled temperature variations (i.e. power plant cooling water) and algal decomposition all degrade water quality. Degradation of water quality eventually results in lower concentrations of dissolved oxygen, contamination of fish, shellfish, and substrates with heavy metals, toxic chemicals, and disease-bearing pathogens.

The die-off of indigenous shellfish populations due to coastal development, shrinking habitats, and pollution through both point- and non-point source discharges, contributes to the descending spiral in water quality. Bivalve filter feeders, such as oysters, clams, quahogs, scallops, and mussels, represent one of the more efficient, natural, available bio-filtration systems. Filter feeders relative to their size, strain enormous quantities of nutrients and algae from the surrounding water. This process helps to maintain and improve water quality. Once die-off or other forms of population depletion begins, so does an associated increase in nutrients and algae and a resulting decrease in water quality.

COASTAL DEVELOPMENT

The effects of coastal development on shellfish-growing areas is indicated by the increasing acreage degraded by anthropogenic pollution sources from 1985 to 1990. For example, the largest increases are attributed to urban run-off, impacting 23 to 38 percent of harvestable Massachusetts waters. [Division of Marine Fisheries]. The acreage adversely affected by faulty septic systems increased from 22 percent to 37 percent during the same time period. Pollution from septic systems is associated with continuing residential growth, as well as pressure from the increase in tourism and vacation home development. Also indicative of accelerating pressures from coastal recreation is the increase in waters adversely affected by boating, up from 11 to 18 percent (National Shellfish Register, 1991).

Physical alteration of the coastal environment (dredging and filling; erosion and siltation; damming and/or diversion of streams; constriction of estuary mouths by bridges and causeways; construction of malls, shopping centers and housing developments on the waters' edge) has also had significant negative impact. Increasing demand for building sites in coastal communities has

resulted in destruction of tidal wetlands, an important component of the marine ecosystem that provides a habitat and nutrient source for many species.

Since the late 1950s, disease has taken a heavy toll on shellfish populations already weakened and stressed as the result of degraded water. According to the National Shellfish Register, "Preliminary findings suggest that the ability of shellfish to withstand such infection is compromised by environmental pollutant stresses."

In Massachusetts, shellfish populations have historically been regarded as a public resource available to all. Under such conditions, municipal and state agencies must manage shellfish with only limited public funds, relying heavily upon nature to sustain or enhance these natural populations.

Dr. David Belding pointed out "In the early days, when the natural supply was apparently inexhaustible, and practically the entire population resided on or near the seacoast, it was just that all people should have common rights to the shore fisheries. As long as the natural supply was more than sufficient for the demand, no law could have been better adapted for the public good. Now, it is obvious that nature alone cannot be depended upon to sustain these resources."[Profile of the Shellfish Industry in Southeastern Massachusetts, 1930].

SHORT AND LONG-TERM IMPACTS

Acute water quality problems are characterized by sudden, easily recognizable changes in the smell, surface appearance, or turbidity of the water. The most common causes include discharges of chemicals, sudden changes in temperature, the kind of emergency that requires an immediate response; i.e. overturned chemical truck discharging into a receiving stream, an oil spill, etc.

Chronic Water Quality Problems, characterized by low levels of dissolved oxygen, high temperatures, advancing eutrophication, fall-off in indigenous species' populations, are typically caused by frequent, small incidents of water pollution, or "non-point source pollution." The leading probable cause of algal growth, low dissolved oxygen concentrations, salinity and temperature fluctuations, high coliform counts, and resultant lower productivity in coastal shellfish populations are non-point source discharges. [U.S. EPA 1992. The Nation's Water; (OSW No. 24-01-W).

WATER QUALITY IMPACTS ON COASTAL RESOURCE AREAS

Some of the more noticeable effects of degraded water quality are (1) the die-off of eelgrass and other aquatic vegetation, (2) lower levels of dissolved oxygen, (3) contamination of shellfish beds, (4) and the poisoning of fish larvae.

Constant, low-level pollution results in breaking some of the first links in the food chain and killing off organisms upon which small fish feed, thus reducing the quantity of prey available throughout the food chain. Deprived of food and shelter, the populations and species diversity of fish and crustacea decline. Toxic chemicals accumulate, diseases and abnormalities increase. These consequences move up the food chain with more fish, shellfish, birds, and mammals dying or failing to reproduce. These phenomena are not limited to near-shore areas. Many off-shore species spend a portion of their lifetime in the near-shore environment, or depend upon food produced by coastal systems.

Loss of commercial and recreational shellfish catches because of shellfish bed closures due to high coliform counts are directly correlated with human-generated, point source and non-point source discharges. Poorly flushed embayments are particularly susceptible to pollution of shellfish beds. Areas with combined sewer overflows (CSOs) or a high level of recreational boating are also likely to be closed to shellfishing, at least conditionally for portions of the year [Division of Marine Fisheries].

SHELLFISH HABITAT

Quahogs (*Mercenaria mercenaria*), oysters (*Crassostrea virginica*), bay scallops (*Argopecten irradians*), softshelled clams (*Mya arenaria*), surf clams (*Spisula solidissima*), and blue mussels (*Mytilus edulis*) are culturally and economically the most important species in Massachusetts. The most prolific beds, whether wild or cultured, tend to be established in coves, bays, and similar areas where fresh water flows dilute the seawater, tidal action is regular, there is a constant supply of food, and protection is afforded from storms and surges. These beds are subject to greater risk from bacterial or chemical contamination and consequent degradation due to their proximity to human settlements.

Tidal flats also provide a home to many of the cultivated species in Massachusetts. These are shallow, sloping areas composed of materials ranging from very fine silt and clay to coarse sands. Microscopic algae provide nourishment for tidal

flat life, including quahogs, soft-shelled clams, and polycheate worms. It is the combination of salinity, substrate quality, and the character of water movement over the flats that determines the species composition of the plant and animal communities. (Carlozzi, et al. 1975). Contaminants (i.e. TBT anti-fouling bottom paints used on boats) carried to the flats can be taken up by the microscopic algae and worms living in the flat, accumulate in the substrate, accelerate algal growth, lower the dissolved oxygen available, change total salinity, and in turn, impact the shellfish populations by directly killing them or their food sources, or by contaminating them.

PATHOGEN CONTAMINATION

Measurement of fecal coliform is used as an indicator of the possible presence of disease-causing bacteria and viruses. For example, gastroenteritis, hepatitis, and polio are associated with human waste-borne viruses. Shellfishing is prohibited when concentrations reach 14 fecal coliforms per 100 milliliters. Thousands of acres of productive shellfish beds, representing millions of dollars, have been closed to harvesting in recent years because of potential pathogen contamination. Between 1970 and 1990, closed acreage increased by nearly 300% in Massachusetts and Cape Cod Bays. On Cape Cod, over 550 acres are currently closed, a 90% increase from 1980. Closures on the North and South Shores have also been on the rise. Currently, there are over 7400 acres closed to harvesting on the South Shore, and 56,000 on the North Shore. (Buzzards Bay Project, 1990).

Statewide, out of an approximate 1,800,000 acres of waters under state jurisdiction, 67% (1,199,537) are classified as approved (for direct consumption), 5% (88,887) are classified as prohibited (no harvest of any kind), 28% (498,705) are closed because they are unclassified (lack of sanitary survey) and less than 1% (454 or 1416) are classified as Restricted (harvest with depuration). Unclassified areas are not polluted, but rather areas which have not been surveyed mainly due to lack of shellfish habitat. (Division of Marine Fisheries, 1994)

Shellfish that are not directly killed by the discharge of toxics may take them up, either through exposure to contaminated substrates or through feeding. Many shellfish species have the capacity to bioaccumulate toxics to levels that may kill or damage an organism higher up on the food chain.

For a complete description of public health concerns and shellfish contamination, see Chapter Six, Seafood Safety.

WATER QUALITY STANDARDS

The Federal Water Pollution Control Act, 33 U.S.C. section 1251 et seq. and the Massachusetts Clean Waters Act, M.G.L. c. 21 sections 26 - 53, require the development and update of water quality standards to restore and maintain the chemical, physical, and biological integrity of the Nation's waters.

Massachusetts defines "water quality standards" as the criteria necessary to sustain particular uses of various water bodies, as well as to upgrade the water for prospective, designated uses. Water quality standards are developed and evaluated by the Massachusetts Department of Environmental Protection, Division of Water Pollution Control.

314 CMR 4.00: Surface Water Quality Standards, classifies all of the waters of Massachusetts, inland and coastal, into categories based upon the present condition of the water, prescribes minimal water quality criteria to maintain present water quality, and prescribes "antidegradation" requirements to upgrade water quality.

Categories

The regulations divide surface water into Classes in order to maintain or upgrade the uses available when classified; i.e. drinking water, recreation, etc. For coastal and marine waters, the classifications are as follows (314 CMR 4.03):

Class SA - waters designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas.

Class SB - waters designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting with depuration (Restricted Shellfish Areas).

Class SC - waters designated for the protection and propagation of fish, other aquatic life and wildlife, and secondary contact recreation.

Parameters and Criteria for Evaluation

The criteria applied to evaluate and classify coastal and marine surface water are (314 CMR 4.03): overall aesthetics, presence and amounts of radioactive substances, presence and amounts of tainting substances, color, turbidity, amount of total suspended solids, presence and amounts of oil and grease,

presence and amounts of nutrients, presence and amounts of other constituents, amount of dissolved oxygen, temperature increase, pH level, amount of total coliform bacteria, and amount of fecal coliform bacteria.

Antidegradation

The regulations require that the present quality of surface water be maintained and protected from degradation. To accomplish this, the following requirements are included at 314 CMR 4.04:

> (1) Protection of Existing Uses. In all cases, from and after the date these regulations become effective, the quality of the surface waters shall be maintained and protected to sustain existing beneficial uses.
>
> (2) Protection of High Quality Waters. From and after the date these regulations become effective, waters designated by the Division in 314 CMR 4.05(5) whose quality is or becomes consistently higher than that quality necessary to sustain the national goal uses shall be maintained at that higher level of quality unless limited degradation is authorized by the Division.
>
> (3) Protection of Low Flow Waters. Certain waters will be designated...for protection under 314 CMR 4.04 due to their inability to accept pollutant discharges. New or increased discharges of pollutants to waters so designated are prohibited unless a variance is granted by the Division...
>
> (4) National Resource Waters. Waters which constitute an outstanding national resource...shall be preserved. These waters shall be designated for preservation by the Division.... Waters so designated may not be degraded and are not subject to a variance procedure. Existing discharges shall be eliminated unless the discharger is able to demonstrate that:
>
> > (a) Alternative means of disposal are not reasonably available or feasible; and
> >
> > (b) The discharge will not affect the quality of the water as a national resource.

(5) Control of Eutrophication. The discharge of nutrients, primarily phosphorus or nitrogen, to surface waters will be limited or prohibited... as necessary to prevent excessive eutrophication of such waters... . Existing discharges

containing nutrients which encourage eutrophication or growth of weeds or algae shall be treated. Activities which may result in non-point source discharges of nutrients shall be conducted in accordance with the best management practices reasonably determined by the Division to be necessary to preclude or minimize such discharges of nutrients.

CHAPTER FIVE - LEGAL/REGULATORY

The utilization of public and private resources in the coastal zone lies at the bottom of a complex, often confusing mix of federal, state, and local requirements and rules governing aquaculture.

There are several federal, state, and local determinations, permits and/or licenses required to engage in coastal aquaculture. The number of agencies and governments involved, and the corollary amount of paperwork required, will vary with the type of aquacultural activity engaged in. The system is a three-tiered one (local,state and federal), reflecting the policy positions, general conditions, and specific local requirements for engaging in aquaculture.

For example, local cities and towns are concerned about managing conflicting land and water uses, such as recreational beach use, areas set aside for recreational boating, coastal development, and public access. Local conservation commissions are concerned about natural resource protection, as they must implement the state Wetlands Protection Act. In addition, local economic conditions are significant factors in the determinations of coastal cities and towns when considering the licensing of particular areas for shellfish grants. In Massachusetts, local authorities with a hand in coastal aquaculture include boards of selectmen/ mayors, conservation commissions, shellfish officers, and harbormasters.

The Commonwealth of Massachusetts has additional concerns. Protection, maintenance, and enhancement of the state coastal zone, coastal wetlands, endangered species, ocean sanctuaries and areas of critical environmental concern are all state priorities. Of similar concern is the protection of local species and water quality. The licenses and permits applicable to aquaculture in Massachusetts, including surface water discharge permits, water quality certifications, waterways licenses, state aquaculture permits, reflect the state agenda. In Massachusetts, the agencies relevant to coastal aquaculture are the Executive Office of Environmental Affairs/Coastal Zone Management, the Department of Fisheries, Wildlife, and Environmental Law Enforcement/Division of Marine Fisheries, the Department of Environmental Protection, Department of Environmental Management, Division of Wetlands and Waterways, and the Department of Food and Agriculture.

The federal government, through the U.S. Army Corps of Engineers, the Coast Guard, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service and the U.S. Environmental Protection Agency, implements a broad national agenda: the assurance that United States navigational routes are maintained, that marine mammals and endangered species are protected, that

waters of the United States are not degraded. The permit and review programs that have application to coastal aquaculture, including the National Environmental Policy Act, dredge and fill permits in navigable waters, and national pollution discharge elimination system permits, protect and advance these policies.

The following overview provides a broad look at the three tiers governing coastal aquaculture.

LOCAL PERMITS

Local Issuance of Section 57 Shellfish Licenses

Shellfish licenses are issued by coastal cities and towns under the authority of Massachusetts General Law chapter 130, section 57, for a period of ten (10) years, with a right to request renewal. A shellfish license authorizes a named individual a) to plant and grow shellfish, whether bottom or water column culture; b) to place shellfish in or under protective devices affixed directly to the tidal flats or land under coastal waters, such as boxes, trays, pens, bags, or nets; c) to harvest and take legal shellfish; d) to plant cultch for the purpose of catching shellfish seeds; and e) to grow shellfish by means of racks, rafts, or floats.

Section 57 was amended on July, 10 1994 to eliminate the distinction between bottom culture and water column licenses (previously issued under section 68A); all licenses for shellfish aquaculture will now be issued under the procedures found in section 57.

In order to obtain a license, an application under section 57 must be submitted to the municipality. The exact form of a licensing application and the amount of fees payable vary to some extent among municipalities. The Mass. Division of Marine Fisheries (DMF) must certify that issuance of the license will have no adverse effect on the shellfish or other natural resources of the town. This is accomplished by conducting an inventory of existing resources by a DMF biologist at the site. The survey will consist of a description of the total size of the proposed area to be licensed, the sediment composition of the proposed area, the number of transects used for sampling of naturally-occurring shellfish, the method used to conduct the sampling, and the number, species, and size of naturally-occurring shellfish found in the sampling area. DMF must also examine the public record to consider other issues raised, which may include other fisheries, endangered species, eelgrass, etc. If DMF concludes that "no adverse effect" will occur, the area will be certified by DMF.

Issuance of the license does not convey any property rights to the aquaculturist. While Massachusetts honors the public trust rights of fishing, fowling, and navigation in the intertidal zone, it is one of the few states in which private property extends to the low water mark. The Mass. Supreme Judicial Court has recently ruled, in Pazolt v. Director of the Division of Marine Fisheries, et. al., (April 20, 1994) that aquaculture is not part of the public trust right of fishing, and therefore aquaculturists must obtain permission from the private property owner in order to practice aquaculture (generally placing structures, such as nursery trays or boxes), in the intertidal zone.

Local Administration of the Mass. Wetlands Protection Act

Massachusetts General Law chapter 131, section 40 requires anyone who intends to "remove, fill, dredge, or alter" any coastal resource area, including wetlands, beaches, flats, dunes, land under the ocean, and land subject to tidal action or coastal storm flowage, to file an application called a Notice of Intent with the local conservation commission and receive a permit, called an Order of Conditions, before proceeding. While the "normal maintenance or improvement of land in ...aquaculture use" is exempt from the Wetlands Protection Act, new or expanding operations must file with the conservation commission.

Since conservation commission jurisdiction extends to the limits of municipal jurisdiction (3 miles), any shellfish or finfish operation within that area which impacts land under the ocean would be subject to conservation commission review. The placement of nursery trays and boxes for shellfish cultivation typically qualifies as a regulated activity under this section. In addition, access (particularly vehicular access) to and from the aquaculture operation may also require the filing of a Notice of Intent if the activity will impact or occur within 100 feet of a number of wetland resource areas, such as dunes, banks or beaches.

An applicant who is unsure of the conservation commission's jurisdiction may file a "Request for Determination of Applicability" with the commission for a relatively quick ruling as to whether a full Notice of Intent will be required.

The wetland regulations (310 CMR 10.00 et seq.) provide all necessary forms. The applicant may also obtain forms from the local conservation commission. Upon submission of a completed Notice of Intent, including a description of the proposed work, resource areas, plans, and payment of a filing fee, the conservation commission will conduct a hearing on the Notice of Intent and either issue the applicant an Order of Conditions authorizing the aquacultural activity and setting forth specific terms and conditions under which the activity (i.e. placement of clean sand) shall be conducted; or deny the application if it

cannot be conditioned to protect the interests of the wetlands act.

Appeals may be taken to the regional office of the Department of Environmental Protection (DEP); such appeals are called Requests for Superseding Orders of Conditions.

A number of communities also have their own wetlands protection bylaws which may require additional permits for aquaculture operations. Some wetland bylaws are found in local zoning codes, while other wetland bylaws are "general," i.e. promulgated under constitutional Home Rule powers, with procedures and standards similar to but usually more stringent than the state wetlands act. Appeals of local bylaw decisions are usually to Superior Court.

STATE PERMITS

Marine Fisheries

General Law chapter 130 provides the primary authority for regulation of activities concerning or affecting aquaculture in Massachusetts. The statute is broadly drawn and includes provisions for state agency authority and oversight of coastal and marine fishing, licensing and permitting, coastal pollution, riparian rights, reporting requirements, specific coastal and marine species, commercial and business activities, wetlands protection, and shellfish activities. The chapter also vests the authority to promulgate rules and regulations for the implementation of this chapter in the Division of Marine Fisheries (DMF) within the Department of Fisheries, Wildlife, and Environmental Law Enforcement.

Section 57 of chapter 130, governing the licensing of shellfish areas for aquaculture, is discussed in the paragraphs above on local permits. Additional sections of chapter 130 that may be of interest to the coastal aquaculturist include section 17B aquacultural enterprise permits. Application may be made to the DMF for a permit to possess, take or harvest any fish out of season and outside of the size limitations if (1) it is for use in aquaculture and (2) it is kept separate from natural stock of the same species. This permit would not apply where shellfish seed is re-planted on flats and not held separately from whatever limited natural stock might exist, but is applicable to the sale of seed shellfish.

In addition, DMF issues section 69 Permits (under the authority of 322 CMR 7.01, 3.03) for possessing or importing seed quahogs, clams, oysters, and scallops.

The Mass. Waterways Licensing Statute

Mass. General Law Chapter 91 protects and manages Massachusetts tidelands and waterways promoting a balance among the many competing public and private uses of the coast. Specific circumstances, provisions, obligations, and requirements are articulated in the regulations promulgated under c. 91 at 310 CMR 9.00 et seq.: Administration of Waterways Licenses.

Chapter 91 also protects the public's property rights in coastal (as well as in many inland) waterways. Below the low water mark in tidal areas, the state owns all land and water outright, while in the intertidal zone, the public has an easement to enter for the purposes of fishing, fowling, and navigation. The Commonwealth also owns the state's Great Ponds, and protects the public right of navigation on most inland rivers and streams.

In addition to direct ownership rights, the Commonwealth regulates and licenses water-dependent uses such as maritime commerce and transportation, fishing (including shellfishing), recreational boating and swimming, and other activities which enable the public to use and enjoy the waterfront.

Certain aquaculture activities, including bottom, off-bottom culture and fish farms could be required to submit applications for waterways permits or licenses.

Permits under chapter 91 must be obtained from the local harbormaster for the placement on a temporary basis of moorings, floats or rafts held by bottom-anchor. If the aquaculture activity fits this description, no additional permit is needed from DEP under chapter 91.

A chapter 91 license is required for fill or structures in tidelands; the definition of "structure" includes any weir, boom, breakwater, line, or wire, plus any pile-held or permanently fixed float or aquaculture gear. Structure does not include any mooring, float or raft which has received an annual permit from the harbormaster, nor does it include any weir, pound net, or fish trap that has been approved by DMF.

If a license is required, the applicant must provided detailed information on the project, including plans prepared by a registered professional engineer or a land surveyor; must pay occupation and tidewater displacement fees; and must comply with all substantive standards for environmental protection, water-related public rights (navigation, fishing, fowling, free passage), protection of existing water dependent uses, and engineering and construction standards. If the project is located in an Ocean Sanctuary, the applicant must demonstrate during the Chapter 91 process, that the project meets the "public necessity and

convenience" requirement of the Ocean Sanctuary Act. Once approved, the applicant is given a long-term, recordable license for exclusive use of the area.

The Mass. Environmental Policy Act

Prior to the issuance of many state permits, the requirements of the Massachusetts Environmental Policy Act, G.L. chapter 30, sections 61-62H, (MEPA), must be satisfied. MEPA is administered by the Executive Office of Environmental Affairs, MEPA Unit, with regulations at 301 CMR 11.00. MEPA requires the state to review, for environmental impacts many direct state activities, plus many projects that use state funding or require issuance of a state permit or license. The need for review is typically triggered by the size of the project and type of state activity (permitting, funding etc.) involved; specific thresholds are listed in the regulations and should be consulted for each proposed project. Aquaculture projects will not likely require MEPA review unless the site is located in an ACEC and the project action is appealed to DEP. Other examples of MEPA thresholds that may be of concern to the coastal aquaculturist include:

* any project resulting in the dredging, filling, alteration or removal of one or more acres of bordering vegetated wetland or salt marsh, or ten or more acres of any other resource area protected by the wetlands regulations;

* any project needing a Superseding Order of Conditions from the DEP that includes: any fill or structure within a regulatory floodway of rivers or streams delineated under the National Flood Insurance Program; alteration of a primary dune; construction in a velocity zone on a barrier beach; new, expanded, or reconstructed armoring of a coastal bank; the alteration of 1000 square feet or more of salt marsh, or 5000 square feet or more of bordering vegetated wetland, or 500 feet or more of bank, or 1/2 acre or more of any other area subject to the wetlands protection act;

* licensing under c. 91 of any solid fill structure of 1000 square feet or more base area, or pile-supported structures of 2000 square feet or more; and

* any project located in an area of critical environmental concern that needs a state permit or license listed in the thresholds (301 CMR 11.26).

If a listed threshold is met, an Environmental Notification Form (ENF) must be filed, describing the proposed project, the potential for environmental impacts, and the alternatives available that would avoid or minimize damage to the environment. The

Executive Office of Environmental Affairs, through its MEPA Unit, will publish and review the ENF in the Environmental Monitor, hold a meeting with state and local agencies, and the public, to identify environmental issues, review any written comments received about the ENF and make a determination about whether further environmental information in the form of an Environmental Impact Report (EIR) is required.

If no EIR is required, there is no further obligation under MEPA and the appropriate state permits may be issued. If an EIR is determined to be necessary, the applicant will have to file the EIR, describing in detail the proposed project, alternatives to the proposed project, a description of the existing environment, an analysis of environmental impacts and the mitigation measure(s) that may be employed to avoid, or if not possible, to minimize negative impacts. The EIR, as was the ENF, will be published and reviewed by the public, state, local agencies and MEPA. Once the Final EIR has been reviewed and certified as complete, the permitting agencies are free to act on the project; each permitting decision must contain a finding (called a Section 61 finding) that all feasible measures have been taken to avoid or minimize damage to the environment.

Surface Water Quality Discharge Program

The Massachusetts Clean Water Act, G.L. c. 21 sections 26 - 53, establishes a management structure for the protection and maintenance of the quality of the waters of the Commonwealth.

Section 43 of the Act establishes a program, implemented through the regulations promulgated at 314 CMR 3.00: Surface Water Discharge Permit Program, regulating the discharge of pollutants into the waters of the Commonwealth. These permits are issued jointly with EPA's National Pollution Discharge Elimination System (NPDES) permits described below.

Any activity resulting in a discharge into Commonwealth waters may be subject to the requirements of the surface water permit program and an anti-degradation demonstration. As an example, an aquaculturist establishing a shellfish hatchery might utilize one influent line and one effluent line. Whatever is discharged from the effluent line, such as circulating water, water used to carry nutrients and wastes from seed trays, etc., would be subject to the effluent limits established under the NPDES permit.

Other Permits or Requirements

The above permits and licenses are generally required of all aquaculture projects located in state waters. Other state agencies

may review many aquaculture proposals via MEPA and ACOE interagency reviews. For example, the Department of Environmental Management reviews MEPA, Chapter 91 and ACOE applications with an eye for projects located in Massachusetts Ocean Sanctuaries (generally speaking, all state waters (below mean low water) with the exception of the area between Lynn and Marshfield. The Ocean Sanctuaries Act derives its authority under Mass. General Laws, Chapter 132 A, Sections 13-16 and 18 and regulations 302 CMR 5.00. This Act is designed to protect coastal waters by prohibiting activities that could be environmentally or aesthetically damaging. To date, DEM has not taken jurisdiction over any aquaculture project.

STATE CERTIFICATION OF FEDERAL PERMITS OR LICENCES

Water Quality Certification

Section 401 of the federal Clean Water Act (33 U.S.C. 1344), requires states to certify that federal actions, such as the issuance of federal permits or licenses that allow discharges to state waters, comply with state water quality standards. Typically, DEP issues a water quality certification for 1) point-source discharges allowed by federal NPDES permits; and 2) the discharge of dredged or fill materials allowed under federal section 404 or section 10 permits. These federal programs are discussed more fully below. DEP is in the process of promulgating new regulations for the 401 program that are compatible with the Army Corps of Engineers Programmatic General Permit (also discussed below). Aquaculture projects that meet certain criteria identified in the new regulations will not need individual water quality certification.

Coastal Zone Management Federal Consistency Certification

Similarly, the Mass. Coastal Zone Management Office must certify federal actions, including the issuance of licenses and permits, to ensure they are consistent with the state Coastal Zone Management Program. The Mass. Coastal Zone Management Program contains 27 broad policies that can be found in 301 CMR 20.00. These policies provide the state with an important tool, as they are often the only state standards and review applicable to aquaculture operations in federal waters (i.e. any project beyond the 3 mile limit or the bay closure lines). Federal permits relating to aquaculture which could trigger the Consistency requirement include ACOE Section 10/404 permits, New England Fisheries Management Council actions and NPDES permits.

Permits For Dredged or Fill Materials and Permits For Affecting or Obstructing Navigation

Section 404 of the federal Clean Water Act (33 U.S.C. 1344), requires a permit for the discharge of dredged or fill material into the navigable waters at specified disposal sites.

Section 10 of the Rivers and Harbors Act of 1899 requires a permit for any activity affecting or obstructing navigable waters.

On August 24, 1993, the Army Corps of Engineers issued a Programmatic General Permit (PGP) to administer both of these programs in Massachusetts. The PGP has been monitored and evaluated for effectiveness over the last few months and will most likely be extended, with slight modifications, for an additional five years.

The PGP provides a simplified review process for minimal-impact projects that fall within the Corps' permitting jurisdiction. Most aquaculture activities will fall under "Category II - Screened PGP" activities. Category II Projects will be screened by the Corps of Engineers and the federal resource agencies (Environmental Protection Agency, U.S. Fish and Wildlife Service, and National Marine Fisheries Service) for a case-by-case determination of the applicability under this general permit.

Substantively, the Corps will look to its previously issued "Letter of Permission" for guidance in determining whether to issue the PGP or to require an individual permit for shellfish operations. The Letter of Permission (dated August 21, 1991) established information requirements (i.e. the proposed work, the location of the proposed license, a description of fill activities (importation of clean sand for nursery trays and subsequent discharge of naturally-occurring dredged sand to the surrounding substrate) and a description of the natural resources and bottom sediments in the grant) and a series of universal conditions that must be satisfied by an applicant.

In order for an aquaculture applicant to receive a PGP, all other state and local permitting conditions must be satisfied; i.e. Order of Conditions, a section 57 license, chapter 91 permit, etc. For these projects, applicants should submit a permit application to the Corps; applicants filing a Notice of Intent (NOI) with their local Conservation Commission should submit a copy of their NOI materials to the Corps at the same time they apply to their Commission, along with additional information concerning the work within Corps jurisdiction.

Screened projects may not proceed until written notification is received by the ACOE and the applicable certifications or waivers concerning water quality and coastal zone management are received by the applicant.

National Pollution Discharge Elimination System Permit

Section 402 of the federal Clean Water Act, (33 U.S.C. 1342) requires a permit for any activity resulting in the discharge of any pollutant, or combination of pollutants into navigable waters. These permits, called NDPES permits, are issued jointly with the state. As an example, an aquaculturist establishing a shellfish hatchery might utilize one influent line and one effluent line. Whatever is discharged from the effluent line, such as circulating water, water used to carry nutrients and wastes from seed trays, etc., would be subject to the effluent limits established under the NPDES permit.

National Environmental Policy Act

In some cases, particularly for large projects or those expected to have significant environmental impacts, the requirements of the National Environmental Policy Act, 42 U.S.C. 4321, (NEPA) may need to be satisfied. The burden is on the federal agency proposing the action (such as permit or license issuance) to identify environmental impacts, to avoid and minimize those impacts, and to explore alternatives that may be less environmentally damaging. An environmental assessment, or if the project is significant and controversial, an Environmental Impact Statement (EIS) is prepared by the permitting agency.

The New England Fisheries Management Council (NEFMC)

Aquaculture projects located in federal waters could be required to obtain an authorization from the NEFMC to site facilities. No precedent exists for this type of authorization off of Massachusetts state waters although a proposal for sea scallop aquaculture is now before the Council.

CHAPTER SIX - SEAFOOD SAFETY/PUBLIC HEALTH

Public health issues surrounding the quality and safety of wild and cultured shellfish have been a source of general concern throughout the industry. Much negative information and publicity, especially concerning water pollution and contaminated shellfish areas, has increased public awareness about the potential dangers of eating shellfish, particularly shellfish that has not been adequately stored or cooked.

As discussed earlier, bivalve mollusks are filter feeders, straining particulate food from surrounding water (and absorbing elements through substrate). The particulates are caught on the gill surfaces and are transported to the digestive tract. Because of their ability to filter significant quantities of water in relation to their size and the ability to retain microorganisms in the size range of bacteria and viruses, shellfish may ingest and concentrate undesirable pathogens, as well as toxic pollutants and heavy metals, during the filtering process. Some bivalves are so efficient that they may concentrate and/or exceed 1000 times the ambient contaminant concentration. (Chang, 1991) Many of these pathogens may have little effect upon the shellfish, but could be devastating to a consumer.

HISTORY

It has been known for years that shellfish harvested from polluted areas can cause illness, particularly if eaten undercooked or raw. Toxins such as pesticides, hydrocarbons, heavy metals, radioisotopes, and marine biotoxins all may be successfully concentrated by shellfish. The major public health concern historically however, has been with the pathogenic bacteria like Salmonellae and viruses capable of causing hepatitis-a, gastroenteritis, and polio.

PATHOGENS

Fecal coliform bacteria, which lives in the intestines of warm-blooded animals, has traditionally been used as an indicator of sewage pollution. Evidence of fecal contamination in turn, indicates at least the potential presence of pathogens. Therefore, classification of shellfishing is based upon the concentration of fecal coliform bacteria in overlying waters.

According to the National Shellfish Sanitation Program, shellfish growing areas may be approved if, on the basis of

fifteen sets of samples taken under adverse pollution conditions as described by the sanitary survey, they meet the following criteria:

1) the median number of total coliform bacteria in the water does not exceed 70 per 100 ml of water sampled, and not more than 10 percent of the samples have a count in excess of 230 per 100 ml, or

2) the median number of fecal coliform bacteria - bacteria associated with the feces of warm-blooded animals - do not exceed 14 per 100 ml, and not more than 10 percent of the samples have a count in excess of 43 per 100 ml.

The methodology is not by any means foolproof. There are problems associated with the use of total coliforms or fecal coliforms being relied upon as the indicators of the level of sewage contamination. The actual degree of risk of infection posed by human pathogens is also uncertain. Coliform counts may mislead, as follows:

1) sewage treatment plants generally use chlorine to sterilize effluent. Although chlorine does reduce bacterial contamination, it may have little effect upon virus populations. In that circumstance, the lack of coliform bacteria in a sample may not indicate the absence of viruses;

2) *Escherichia coli* (primary fecal coliform component) has a lower survival rate in seawater than other organisms, including viruses. Therefore, concentrations of *E. coli* may lead to an underestimate about the risk of other pathogens;

3) *E. coli* in seawater may assume other, non-detectible forms, resulting in false (low) numbers of indicators reported;

4) there are many pathogens that flourish in water that are not associated with fecal contamination and may not be tested for or detected.

NATURALLY OCCURRING PATHOGENS

Vibrio

Concern has been expressed that fish farms could lead to increased numbers of bacteria that cause disease in humans. Sedimentation and organic-loading of finfish waste products could result in uptake, accumulation, and transmission of human pathogens through vectoring shellfish. These concerns have been directed specifically towards the bacteria genus *Vibrio*, since

the genus is common in marine systems and includes fish, shellfish, and human pathogens.

The genus *Vibrio* contains approximately 20 species. Five of the species, *V. cholorae*, *V. parahaemolyticus*, *V. vulnificus*, *V. alginolyticus*, and *V. mimicus*, are known human pathogens, and the pathogenicity of two other species, *V. fluvialis* and *V. metschnikovii*, is unclear. *V. anguillarum* and *V. ordalii* infect salmonids, but there is no evidence to suggest that these species are human pathogens.

In humans, *Vibrio* infections most frequently cause gastroenteritis. The clinical symptoms include diarrhea, abdominal cramps, nausea, and vomiting. The disease is normally mild to moderate in severity, and symptoms typically persist for a few days. Exposure to *Vibrio* suspended in seawater can also cause earaches and wound infections. Primary sepsis, caused by *V. vulnificus*, is the most serious of the *Vibrio* diseases. Infection occurs most frequently in persons with chronic liver disease. The *V. vulnificus* infection causes fever, chills, and nausea, and results in death in about one half of the cases. (NSSP Operations Manual, 1992 Revision).

Vibrio bacteria, including pathogenic and nonpathogenic species, are common members of the microbial community in estuarine environments throughout the world. They play significant roles in nutrient recycling and are probably the principle bacterial group responsible for the mineralization of refractory organic materials like chitin. (Cabrizzi, 1990)

The fact that potentially pathogenic *Vibrio* species are widespread but the incidence of infection is relatively low is probably attributable to three factors. First, not all strains of a pathogenic species are virulent. Second, many pathogenic *Vibrios* require water temperatures above 15 degrees C. Finally, the incidence of *Vibrio* infection is minimized by cooking seafood and killing the bacteria. *Vibrio* infections are contracted by eating raw seafood, inadequately cooked seafood, or cooked seafood which is subsequently left in contact with raw seafood.

Concerns that aquaculture could lead to increased incidence of *Vibrio* infections are based on two facts. First, *Vibrio* suspensions have been found in greatest abundance in areas characterized by high inputs of organic matter and/or particulate material. Such conditions may exist in the vicinity of fish farms. Second, filter-feeding mollusks concentrate bacteria through normal feeding activities. Thus, there is a potential route for human infection if a fish farm promotes increased Vibrio suspensions in the vicinity of harvestable shellfish. Shellfish in these circumstances could not be harvested for direct human consumption.

There is no current evidence to conclude that fish farms contribute to the proliferation of bacteria species and strains pathogenic to humans.

NATURALLY OCCURRING BIOTOXINS

Shellfish contaminants can take the form of naturally-occurring toxins, such as certain phytoplanktons that tend to bioaccumulate in warm weather, microbiological contamination where the shellfish acts as a vector for disease transport to humans, and bioaccumulation of toxics, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs).

Paralytic Shellfish Poisoning (PSP)

Quahogs, soft shell clams, oysters, and mussels may act as transmission vectors for paralytic shellfish poison (PSP) to humans. PSP results from the ingestion of saxitoxin, an extremely potent toxin produced by the dinoflagellate *Alexandrium tamarensis*.

Anyone who has lived in a coastal area has experienced the phenomenon known as "red tide." Under certain conditions; high water temperatures, calm seas, low salinity, and high-nutrient content, certain naturally occurring plankton will experience population explosions, resulting in tremendous quantities of planktonic organisms reproducing at a massive rate in a very short period of time. It should be noted that all such population explosions may not be toxic and may not discolor sea water; this is dependent upon the kind of organism experiencing the rapid growth, or "bloom." Toxic red tides on the east coast are primarily caused by the dinoflagellate *Alexandrium tamarensis*. Shellfish ingest this organism and accumulate toxins in their bodies. This accumulation has no ill effect on the health of the shellfish directly, but if consumed by humans, can result in PSP. This toxin is particularly dangerous because it will not be eliminated by cooking and does not change the appearance of a contaminated mollusk. (Northeastern Marine Advisory Council, 1987)

PSP acts quickly. The onset of symptoms will usually occur within thirty minutes of ingestion, causing tingling in the lips, face, neck, and extremities. This is followed by headache, dizziness, nausea, and occasionally vertigo. In cases of severe poisoning, muscular paralysis and respiratory failure may occur, which can be fatal.

All shellfish-producing states have monitoring programs for PSP. In Massachusetts, the Department of Fisheries, Wildlife and

Environmental Law Enforcement maintains a testing and monitoring program. DMF, with laboratory assistance from DEP, conducts a monitoring program in shellfish growing areas while DPH monitors shellfish in the marketplace. In the event that tolerance levels for saxitoxin are exceeded in tested shellfish or shellfish growing areas, the shellfish are seized and destroyed, the growing areas are posted and closed, and local cities and towns are notified.

THE NATIONAL SHELLFISH SANITATION PROGRAM

In 1925, the National Shellfish Sanitation Program ("NSSP") was created, the result of a cooperative effort between the shellfish industry, the U.S. Public Health Service (now the Food and Drug Administration) and cooperating states. The goal of the program was to design uniform standards, applied to all participating states, for the maintenance and oversight of shellfish sanitation in growing areas, in harvesting, and in processing. Uniformity was critical; all participating states embraced the same standards to assure consumers of a uniformly healthful product and to eliminate any competitive advantage a state could obtain by not adhering to the same sanitary requirements. Participation in the program is not mandated by law, but a state who does not participate cannot engage in interstate shipment or distribution of shellfish.

The basic obligations of all participating states are as follows:

1. All states shipping shellfish have to adopt adequate laws and regulations for the sanitary control of the industry; complete and maintain sanitary surveys of growing areas, delineate and patrol restricted areas, inspect shellfish plants and laboratories, and implement measures to insure that all shellfish reaching consumers have been grown, harvested, and processed in a sanitary manner. The state agrees to issue numbered certificates to shellfish dealers complying with the sanitary standards and copies of the certificates are then forwarded to the Food and Drug Administration ("FDA").

2. The FDA makes an annual inspection of each state shellfish control program, including the inspection of a representative number of shellfish processing plants. Based upon this information, the FDA determines the degree of conformity the State program has with the NSSP. Based upon this information, a monthly list is generated of the valid interstate shellfish shipping certificates.

3. The private sector has adopted and augmented this management structure and created its own, additional sanitary standards, including tracking mechanisms to record the shipping and final disposition of the shellfish.

In 1982, the NSSP created an organizational structure utilizing the expertise of shellfish control officers, the FDA, cooperating state representatives, and industry officials; the Interstate Shellfish Sanitation Conference ("ISSC"). The ISSC adopted the NSSP Operations Manual in 1983, as well as a process to revise and amend the provisions of the manual.

In 1983, the ISSC adopted the NSSP Operations Manual as the formal statement of standards for shellfish sanitation. In 1984, the FDA entered into a Memorandum of Understanding with the ISSC as the basis for a continuing, cooperative relationship between the states, private industry, and the federal government.

In 1985, the NSSP Manual was formally codified by the FDA and published as regulations in the Federal Register (50 FR 7797, February 26, 1985).

The NSSP Manual is divided into two parts, reflecting the awareness that the growing and processing of shellfish are two distinct processes. Part I: Sanitation of Shellfish Growing Areas is a guide for preparing state shellfish laws and regulations pertaining to the sanitary control of shellfish growing area classification, laboratory procedures, relaying, patrol operations, and marine biotoxins. Part II: Sanitation of the Harvesting, Processing and Distribution of Shellfish is a guide for operating, inspecting, and certifying shellfish shippers, processors and depuration facilities and for controlling interstate shipments of shellfish.

The Manual also provides specific protocols for Reviewing Classification of Areas Implicated in Shellfish Related Illnesses (Appendix H), Reviewing Classification of Areas Implicated by Pathogens in Shellfish Meat Samples (Appendix I), and Approved National Shellfish Sanitation Program Laboratory Tests (Appendix J).

Part I, Section G of the Manual addresses aquaculture. The section is divided into three categories:

Administrative Procedures - state laws and regulations designed to provide an adequate legal basis for sanitary control of aquaculture;

Open Water Aquaculture - the cultivation of molluscan

shellfish in natural shellfish growing areas; and

Shellfish Polyculture and Land-Based Monoculture - the establishment of procedures for issuing permits for shellfish aquaculture, approving culturing sites and boundaries, keeping records, imposing quarantine measures, and developing other control measures as may be necessary, recognizing that the potential for pathogens in land-based monoculture facilities is greater than natural areas and prudent control measures must be used. Further, the use of indicator microorganisms may not be related to their use in natural settings. There are also increased public health concerns related to polyculture, as the potential is greater for contamination of molluscan shellfish with pathogens and animal drugs than in monoculture.

Massachusetts is a participant in the ISSC and subscribes to the standards promulgated by the NSSP. As part of its Coastal Zone Management Program, Massachusetts is developing a protocol for the siting of wastewater treatment plants, using as a condition to be evaluated in the siting process the existence and classification of shellfish growing areas.

The process employed by the NSSP to classify shellfish growing areas assumes the existence of treatment plants in the proximity of shellfish growing areas and assumes the potential for shellfish contamination. This assumption has been a necessary operating premise, as waste water treatment plants have historically been sited near shellfish beds without giving due consideration to the need for clean water.

In Massachusetts, the protection of shellfish resources is one of the factors to be evaluated in determining water quality standards and the consequent uses allowed in that particular body of water. The state Coastal Zone Management Program Policies (Regulatory Policy No. 1 and Non-Regulatory Policy No. 14; see Appendix) require the preservation of shellfish beds and encourage the development of aquaculture. A siting process that considers preserving the water quality necessary to maintain and enhance existing shellfish resources prior to running the risk of degrading that water quality preserves water quality and forwards achievement of coastal resource management goals.

CHAPTER SEVEN -- ECONOMICS OF AQUACULTURE

UNITED STATES

Aquaculture is the fastest growing "agricultural" industry in the United States. In 1990, there were over 100 species cultured; eight species accounted for approximately 70% of total culture, with over 3400 aquaculture operations in the United States. This trend is driven by increased demand for fisheries product and reduced yield from traditional fisheries landings. (National Research Council, 1982)

The estimated U.S. Total Aquaculture Production (including freshwater) has more than doubled from 139,887 metric tons with a total value of over $260 million in 1983 to an estimated 313,518 metric tons with a total value of over $724 million in 1992. (NMFS Statistics Division) The aquaculture industry supports an infrastructure of hatcheries, feed mills, processing plants, equipment manufacturers, and suppliers of specialty services and products, as well as enhancing the natural fishery with juvenile finfish and shellfish seed and spat.

U.S. annual per capita consumption of fish and shellfish has increased since estimates were first made in 1909. At that time the per capita estimate was 11 lbs., in the 1950 and 60's it was well below 5 lbs., and in 1993 it was 15 lbs. (U.S. Department of Commerce, 1993). Most remarkable was the sharp rise in consumption from 1970 (about 4 lbs.) to 1990 (about 5 lbs.) The domestic seafood industry has identified a goal of increasing domestic seafood consumption to 20 lbs/per capita by the year 2000 although this appears unlikely.

It is estimated that 10% - 14% of the fishery products currently consumed in the United States are aquaculturally derived. Changing consumer preferences combined with the reduction in the wild fishery appear to be the dominant factor in the growth of aquaculture. (FDA, 1990)

Most of the United States' demand for seafood is met by imports. The value of imported fisheries products more than doubled during the 1980's, to $9.6 billion in 1989. This resulted in a significant trade deficit - $4.9 billion for all fisheries products and $3.1 billion for edible fish and shellfish in 1989. Imported fisheries products contribute more to the United States' trade imbalance than any other food or agricultural commodity. After petroleum products, imported seafood contributes more to the United States trade deficit than any other natural resources product. (Joint Subcommittee on Aquaculture, 1992)

Despite the trade imbalance, some aquacultured fish products are exported. There has been significant growth in U.S. exports of ornamental fish with exports of $17 million in 1993 and over $10 million in the first half of 1994. (US Department of Agriculture, 1994)

NORTHEAST REGION

The Northeast Region, as covered by the Northeastern Regional Aquaculture Center (NRAC), includes the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, and West Virginia. NRAC estimates the total 1992 farm gate value of aquacultured products in the northeastern United States to be $146,409,000. Cultured shellfish comprises approximately 53 percent of the 1992 regional farm gate value, with oyster production being the single largest segment of the regional industry accounting for roughly 42 percent of the total. Net pen culture of Atlantic salmon and steelhead trout was the second largest category contributing 29 percent to the regional value. (Northeastern Regional Aquaculture Center, 1993)

The state of Connecticut is the largest aquaculture producing state in the region with estimated farm gate sales of $61.7 million, primarily from oyster sales. Maine is the second largest aquaculture producing state in the region with farm gate sales of $42.9 million, largely from pen-reared salmonid. Pennsylvania is the third largest aquaculture producing state, with farm gate sales totaling $11,926,000, dominated by trout culture. New York is the forth largest aquaculture producer, with $9,637,000 in sales, primarily from the Long Island oyster farms. (NRAC, 1993)

Massachusetts follows as the fifth largest aquaculture producer with $8,020,000 in sales. The dominant species in Massachusetts, in order of economic value are: Northern Quahog, oyster, trout, hybrid striped bass, scallops, baitfish/other fish and tilapia. (NRAC, 1993) Trout, striped bass, baitfish/other fish and tilapia are all grown in inland facilities in Mass.

When comparing the aquaculture industries from state to state, it should be kept in mind that the potential for aquaculture to succeed is dependent on several considerations. While some of these considerations are flexible and can be made more accommodating for aquaculture (laws, regulations, policy, business climate, private and public initiatives) others, (tidal range, exposure, biological parameters, flushing rates, temperature, native species) cannot be easily overcome.

Economic success of aquaculture requires maintenance of a high price in the market to offset basic investments and rearing costs per organism and to assure a good profit margin. Price per organism however, is insufficient to insure economic viability. Maintenance of consistently high sales volume is also required.

MASSACHUSETTS

The reported (landing) value of aquacultured shellfish in Massachusetts is difficult to calculate. The Division of Marine Fisheries and municipalities collects annual landing data from aquaculture producers as a part of their reporting requirements under section 35 of Mass. General Law chapter 130. Precise reporting to DMF is not required of aquaculturists and thus the information received and summarized by DMF reflects only the producers who self-reported. As has been mentioned previously in this report, aquaculturists have also historically underreported their landings for various reasons. Due to both the chronic under-reporting that exists within the industry and the lack of any sophisticated, consistent calculation of true value, shellfish aquaculture is both undervalued and overlooked in Massachusetts.

If the real values were consistently reported, the significance of this industry to Massachusetts would become apparent. Although the shellfish aquaculture industry in Massachusetts is not large when compared to other industries in the state, it is important to consider that the industry is located in small Cape Cod towns which have few other year-round industries. To the municipalities where shellfish culture is practiced, this industry is increasingly desirable for economic development.

Total Estimated Values for Cultured Shellfish; 1986 - 1993

The following estimated values are derived from DMF landing data. For the year 1992 estimated values from the Northeast Region Aquaculture Industry Situation and Outlook Report are also provided for the sake of comparison. NRAC compiled its data via individual grower surveys and is likely to be more realistic, but still not precise. The NRAC figure includes production of inland cultured striped bass, trout, baitfish and tilapia. Comparison of the two estimated values of aquacultured products for 1992 reveals the significant problem Massachusetts has with accurate reporting of aquacultural production.

1986 = $ 2,114,026

1987 = $ 318,584

1988 = $ 620,058

1989 =		$ 1,933,145	
1990 =		$ 906,815	
1991 =		$ 1,884,017	
1992 =	(DMF)	$ 863,418	
	(NRAC)	$ 4,000,000	(approx. value of quahogs & oysters)
		8,020,000	(all aquacultured products)
1993 =		$ 1,753,192	

An additional 4.5 market multiplier is utilized by NMFS to conservatively account for the additional value of spin-off jobs, support industries and employment-related benefits.

FUNDING SOURCES

The common constraint shared by almost all aquaculturists is the lack of dependable funding sources, both for start-up and for operational costs. Most federal funding sources are geared toward traditional agriculture and the programs that include aquaculture generally limit it to finfish and inland endeavors. Most private lending institutions in Massachusetts either do not recognize aquaculture as a commercial venture or recognize the high risk of "crop failure" inherent to aquaculture. This financing vacuum forces most aquaculturists to apply for personal loans to get the venture and operating capital they need.

One of the essential keys to success in any industry is its access to reliable sources of funding. Traditional agriculture has relied upon three sources to provide many of its capital needs: the farm credit system, the Farmers Home Administration, and private lenders. Aquaculturists, particularly shellfish culturists, need the same access and the same opportunities.

CHAPTER EIGHT -- CONCLUSIONS

The following conclusions incorporate both issues relating to the aquaculture industry as a whole and to specific types of aquaculture practiced or proposed for Massachusetts. The conclusions summarized here can be characterized as problems which warrant further attention and action.

A Strategic Plan which addresses the Conclusions will be developed through the focussed work of three Working Groups (Regulatory Reform, Environmental Review/Monitoring, Economic Development/Marketing). The conclusions listed below are grouped under the heading of the Working Group most relevant to the issue.

MARINE MONITORING/ENVIRONMENTAL REVIEW

* Protection of coastal water quality is essential to a sustainable wild and aquaculturally derived seafood industry. Shellfish beds closed due to point or non-point pollution sources represent an underutilized resource and lost revenue for coastal Massachusetts.

The state must move forward to remediate and reopen closed wild shellfish beds while at the same time, promoting marine aquaculture for non-productive intertidal and subtidal areas. Marine aquaculture development should not be promoted at the expense of our wild fishery.

* The siting of wastewater treatment plant outfalls historically was done without consideration of adjacent shellfish beds. As a result, shellfish beds located adjacent to outfalls are often restricted or closed due to excessive fecal coliform counts.

* Fecal coliform may not be the best indicator for pathogens and viruses but is uniformly used as the indicator species for shellfish safety.

* The full extent of environmental impacts from aquaculture are uncertain. While it appears from limited studies and experience that aquaculture, if properly sited, does not cause noticeable degradation, the public often has the belief that aquaculture is a polluting industry.

* Despite the numerous permits required to undertake aquaculture, environmental review of aquaculture proposals is fragmented. If MEPA thresholds are not met and a Chapter 91 license not required (which is generally the case), the only opportunity for state level environmental review is at DMF which has limited staff resources dedicated to environmental review of

such proposals. The other state environmental agencies would have a back-door role in reviewing Section 404/10 permits.

* There are concerns that the use of Off-Road Vehicles (ORV's) utilized by shellfish culturists to access the intertidal area may be detrimental to wetlands and oftentimes, endangered species such as piping plovers.

* Financial and staff resources necessary for environmental review, marine monitoring, technical assistance, administration, and enforcement of aquaculture leases are not adequate at the state or municipal levels of government.

ECONOMIC REVIEW/MARKETING

* Bivalve mollusk culture has historically been and is presently, the dominant form of aquaculture in the state. No other type of marine aquaculture is currently under commercial cultivation.

* The lack of an accurate reporting mechanism for marine aquaculture production has resulted in unreliable economic information on this small, but growing industry.

* Aquaculturists are oftentimes not viewed as businesspeople but rather "hobbyists" due to inconsistent reporting of profit and poor recordkeeping. This perception that aquaculture is a hobby and not a viable business has led to difficulties in obtaining technical assistance, bank loans, small business assistance, etc.

* Press coverage of shellfish disease has led to widespread consumer concern or fear over the safety of shellfish. Overcoming this largely erroneous fear has become a marketing hurdle for the aquaculture industry.

* There is no state agency which is explictly responsible for promoting aquaculture. This stems largely from aquaculture having aspects relating to both agriculture and fisheries. Aquacultural practices do not easily fit within one existing agency mandate. There is presently minimal state involvement in aquaculture marketing, small business development and financing.

* Privatization of traditionally government functions (ie: hatcheries, marine monitoring, depuration) could be considered as a means to minimize government costs and encourage private investment in aquaculture.

* The majority of aquaculture research and development is done by the private sector or the academic community in Massachusetts. The role of state and federal research and development is extremely

limited. Research and development needs relating to production technology, disease control, quality control, environmental impacts, and species specific information are holding back the economic potential of aquaculture in Massachusetts.

* Opportunities for aquaculture training and education is extremely limited in the state. Most private aquaculturists are reliant on limited technical assistance from Sea Grant, U-Mass Extension, and other aquaculturists. There are no degree granting institutions with aquaculture programs in the state.

REGULATORY REFORM

* Shellfish culture, fish farms and aquaculture in general, are poorly understood industries in coastal towns. This misunderstanding has sometimes led to distrust and conflict over private and public tideland and submerged land use.

* The aquaculture industry in Massachusetts operates using a mix of private tidelands, public tidelands, state-owned submerged lands (from mean low water to three miles seaward) and probably sometime soon, federally owned submerged land in the Exclusive Economic Zone (EEZ). Multiple use conflicts of these lands are numerous. Wild fisheries, navigation, recreation, aesthetics and environmental protection are some of the competing uses of this land.

* The regulatory requirements for aquaculture are complex and somewhat redundant. It is often unclear to proponents which permits and approvals are necessary from what authorities for different types of aquaculture located in different jurisdictions.

* For the purposes of regulation, aquaculture does not fit precisely into any existing state agency. Instead, it has been fragmented between the Department of Fisheries, Wildlife, and Environmental Law Enforcement and the Department of Environmental Protection. At times, aquaculture is considered an industrial venture, while at other times it is considered fishing or agriculture. As a result, aquaculture is currently faced with regulatory contraints from several directions, but without benefitting from a direct association with any of the administrative agencies.

* Should the New England Fisheries Management Council exercise its jurisdiction over aquaculture projects in the Exclusive Economic Zone (EEZ), the state's role in reviewing such proposals is limited to Consistency review through CZM. CZM has no enforceable policies directly relating to aquaculture.

* There are concerns that the use of Off-Road Vehicles (ORV's)

utilized by shellfish culturists to access the intertidal area may be detrimental to wetlands and oftentimes, endangered species such as piping plovers.

* Financial and staff resources necessary for environmental review, marine monitoring, technical assistance, administration, and enforcement of aquaculture leases is not adequate at the state or municipal levels of government.

* The Chapter 91 program does not currently consider shellfish trays to be "structures" and therefore they do not require any license or permit. Additionally, floating pens are handled like moorings and are generally approved by local harbormasters under section 10A. To date, DEP has not required a license for any intertidal or subtidal aquaculture facility because most operate with mooring systems rather than with fixed structures. Therefore, aquaculturists are permitted to use year to year Chapter 91 permits obtained by local harbormasters to use public lands at no cost. Some large aquaculture operations may choose to obtain a long term license for financing or to reserve the rights for a longer period of time because the annual 10A permits may not offer long term security that is usually needed for these projects.

* Aquaculture leases issued by municipalities are limited to ten year periods with no guarantee of renewal.

* Aquaculturists perceive regulating agencies, both state and federal, as having an adversarial approach to aquaculture review rather than being cooperative or encouraging. Aquaculturists see the need for a gubanatorial policy which supports aquaculture in the state.

* There may be a need for the regulatory structure to differentiate between commercial aquaculture and resource preservation, enhancement of wild fisheries, and experimental endeavors.

NEXT STEPS

This White Paper will be used to stimulate discussion and action from three Working Groups (Regulatory Reform, Environmental Review and Economic Development/Marketing). These Working Groups, made up of government, industry, non-government organizations and academic representatives will develop state strategies for marine aquaculture development.

The **Regulatory Reform Working Group's** mission is to coordinate municipal, state and federal agencies to develop recommendations for a streamlined permitting framework specifically for aquaculture. A streamlined process will minimize the process while

ensuring a coordinated and thorough environmental review. Permitting processes from other states and countries are being evaluated for possible application in Massachusetts.

The **Environmental Review/Marine Monitoring Working Group** is tasked with identifying the range of environmental concerns relating to different types of marine aquaculture and determining appropriate monitoring protocols and environmental review criteria. This group will explore the potential of mapping areas appropriate for aquaculture at the harbor, town and state levels.

The **Economic Development/Marketing Working Group** will identify economic constraints and opportunities for Massachusetts aquacultured products. This group will examine the potential of marketing coops and recommend the appropriate role for the state in aquaculture promotion and development.

The three Working Groups will complete their strategic planning in the spring of 1995 at which time The Marine Aquaculture Strategic Plan for Massachusetts will be released.

GLOSSARY

Cultch - Hard material (usually broken oyster/clam/scallop shells) laid down in intertidal area to attract spat.

Discharge - (Clean Water Act, 33 U.S.C. section 1362) The addition of any pollutant to navigable waters from any point source, (or) the addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.

Ex-vessel price - Price that fishermen receive for their catch. "Off the boat price"

Farm gate value - Price that aquaculturists receive for their products. "off the farm price"

NPDES - National Pollution Discharge Elimination System. Permit issued by the federal Environmental Protection Agency (EPA) for point sources of pollution (ie: outfalls, drains).

Non-point source - Pollution source not confined to a discrete conveyance (i.e. agricultural runoff, return flows from irrigation, and stormwater discharges.)

Point Source - Any discernable, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants may be discharged.

Toxics - Heavy metals such as lead, copper, and mercury as well as a broad class of pollutants known as organics. Organic pollutants include such petroleum based compounds as polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's) and pesticides. Filter feeding bivalves tend to accumulate cadmium and mercury as well as PCB's.

BIBLIOGRAPHY

Federal Government Sources:

Bettencourt, S. and J.L. Anderson. 1990. Pen-Reared Salmonid Aquaculture in the Northeastern United States. U.S. Department of Agriculture, Northeast Regional Aquaculture Center Report 100. Kingston, RI.

Council of Economic Advisors. 1990. Annual Report of the Council of Economic Advisors. Washington, D.C., U.S. Government Printing Office.

Department of Health and Human Services
U.S. Food and Drug Administration, Center for Veterinary Medicine, 5600 Fishers Lane, Rockville, MD 20857

Department of Health and Human Services. November 1990. Aquaculture Educational Needs. (HFV-244).

Joint Subcommittee on Aquaculture (JSA). 1990. National Aquaculture Forum Output.

Joint Subcommittee on Aquaculture. May 1992. Aquaculture in the U.S.: Status, Opportunities, and Recommendations.
Ingersoll, E. 1881. The History and Present Condition of the Fishery Industries. U.S. Department of the Interior. U.S. Government Printing Office, Washington, D.C.

MacKenzie, C.L. 1989. A Guide for Enhancing Estuarine Molluscan Shellfisheries. Marine Fisheries Review, Vol. 51, No. 3, National Marine Fisheries Service.

Manzi, J.J. 1990. The Role of Aquaculture in the Restoration and Enhancement of Molluscan Fisheries in North America. NOAA Tech. Report NMFS 85.

McVey, J. 1989. The National Sea Grant College Program Annual Report on Aquaculture. U.S. Department of Commerce, Washington, D.C.

National Academy of Sciences (NAS). 1992. Marine Aquaculture: Opportunities for Growth. Washington, D.C.: National Academy Press.

National Agriculture Library, Aquaculture Information Center, U.S. Department of Agriculture, 10301 Baltimore Blvd., Room 304, Beltsville, MD

National Aquaculture Development Plan, Vol. 1. 1983. The Joint Subcommittee on Aquaculture of the Federal Coordinating Council on Science, Engineering, and Technology. Washington, D.C.: U.S.

Government Printing Office.

National Oceanic and Atmospheric Administration (NOAA). 1980. National Aquaculture Plan. Washington, D.C.: U.S. Government Printing Office.

National Marine Fisheries Service (NMFS). 1976. National Plan for Marine Fisheries.

National Research Council (NRC). 1978. Aquaculture in the United States: Constraints and Opportunities. Washington, D.C.: National Academy Press.

National Research Council. 1992. Review of World Aquaculture. U.S. Department of Commerce, Washington, D.C.

Northeast Regional Aquaculture Center. 1993. Northeast Regional Aquaculture Industry Situation and Outlook Report.

Putnam, J.J. and J.E. Allshouse. 1991. Food Consumption, Prices, and Expenditures 1968 - 1989. Statistical Bulletin No. 825. U.S. Department of Agriculture. Economic Research Service, Washington, D.C.

U.S. Army Corps of Engineers. 1992 - 1993. Shellfish Grant Inventory, Northeast Region.

U.S. Department of Agriculture (USDA). 1990. Outlook for U.S. Agricultural Exports. Foreign Agricultural Service, Economic Research Service, Washington, D.C.

U.S. Department of Agriculture (USDA). 1991. Aquaculture Situation and Outlook Report. Economic Research Service. AQUA 1., Washington, D.C.

U.S. Department of Agriculture (USDA). 1993. Aquaculture Situation and Outlook Report. Economic Research Service. AQUA 3., Washington, D.C.

U.S. Department of Commerce. 1990. Fisheries of the United States. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

U.S. Environmental Protection Agency. 1992. The Nation's Water. OSW# 24-01-W, Washington, D.C.

Vaughn, J.M. and E.F. Landy. 1986. Public Health Considerations Associated With Molluscan Aquaculture Systems. U.S. Public Health Service, Northeast Technical Services Unit.

State Resources:

Annual Report. 1992. Buzzards Bay Project, Barnstable, MA.

Belding, David, M.D. 1930. Review of the Quahog Fishery in Massachusetts. Department of Fish and Wildlife, Division of Mar8ine Fisheries, Boston, MA.

Belding, David, M.D. 1930. Review of the Scallop Fishery in Massachusetts. Department of Fish and Wildlife, Division of Mar8ine Fisheries, Boston, MA.

Belding, David, M.D. 1930. Review of the Oyster Fishery in Massachusetts. Department of Fish and Wildlife, Division of Marine Fisheries, Boston, MA.

Cape Cod Commission. 1992. Southeastern Massachusetts Shellfish Propagation List.

Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, RI 02881.

Executive Office of Environmental Affairs, Commonwealth of Massachusetts, Boston, MA. July 1990. Metal Conentrations in Marine Fish and Shellfish From Boston and Salem Harbors, and Coastal Massachusetts.

Information and Education Office, Rhode Island Sea Grant, University of Rhode Island, Bay Campus, Narragansett, RI 02882

Hughs, P. 1976. Aquaculture in Massachusetts. Massachusetts Office of Coastal Zone Management, Executive Office of Environmental Affairs, Boston, MA.

Maine State Planning Office. 1987. Establishing the Maine Advantage: An Economic Development Strategy for the State of Maine.

Maine State Planning Office and Department of Marine Resources. 1989. An Aquaculture Production Strategy for the State of Maine.

Massachusetts Office of Coastal Zone Management. 1993. Draft Guidelines for Barrier Beach Management in Massachusetts, pgs. 56 - 60, 80 - 91, 135 - 138. Executive Office of Environmental Affairs, Boston, MA.

Massachusetts Office of Technical Assessment. 1987.

Mayo Associates. 1988. An Assessment of Private Salmon Ranching in Oregon. Prepared for the Oregon Coastal Zone Management Association, Inc., Seattle, Washington.

Northeast Marine Advisory Council. 1987. University of New Hampshire, Seabrook, NH.

Northeast Regional Aquaculture Center, University of Massachusetts, Dartmouth, North Dartmouth, MA.

Owen, Sally. 1978. The Response of the Legal System to Technological Innovation in Aquaculture: A Comparative Study of Mariculture Legislation in California, Florida, and Maine. Coastal Zone Management Journal, Volume 4, Number 3.

Rhode Island Sea Grant. 1992. A Species Profile of the Quahog in Rhode Island.

Sea Grant Advisory Program, Cooperative Extension Service, University of Connecticut, 43 Marne Street, Hamden, CT.

Sea Grant Communications, 30 Coburn Hall, University of Maine, Orono, ME.

Sea Grant Communications, Kingman Farm, University of New Hampshire, Durham, NH.

Academic/Research Sources:

Allen, P. Geoffrey and Michael J. Donohue and David A. Storey. June 1991. Technical and Economic Feasibility of Alternative Aquacultural Production Systems for American Oysters and Other Bivalve Mollusks in New England. Department of Food and Resource Economics, University of Massachusetts at Amherst.

Beal, B.F. 1988. Public Aquaculture in Downeast Maine: The Soft-Shell Clam Story. University of Maine at Machias, Machias, ME.

Beal, Brian F. 1992. Overwintering Hatchery-Reared Individuals of Mya Arenaria: A Field Test of Site, Clam Size, and Intraspecific Density. University of Maine at Machias, Machias, Maine.

Davies, D.S. 1990. Allocating Common Property Marine Resources for Coastal Aquaculture: A Comparative Analysis. Ph.D. Thesis, Science Research Center, State University of New York at Stony Brook, Stony Brook, NY.

Hall-Arber, M., Ph.D. 1991. Water Pollution and Water Quality in Massachusetts' Coastal Zone. MIT Sea Grant College Program, Cambridge, MA.

Institute of Medicine (IOM). 1991. Seafood Safety. Washington, D.C.: National Academy Press.

Ludwig, Michael and Susan Mello and Christopher Mantzaris. 1990. Mariculture in the Waters of the Northeastern United States: A Regulatory Overview of the Developing Conflicts and Possible Solutions. Environmental Auditor, Vol. 1, No. 4, pp. 205 - 208.

Matthiessen, G.C. 1992. Perspective on Shellfisheries in Southern New England. The Sounds Conservancy, Inc., Essex, CT.

National Sea Grant College Program Forum for Restoration of the American Oyster Industry. 1990. Sea Grant Publication VSG-90-02.

Pei, Chang. 1991. Detection of Pathogens for Shellfish Health Inspections, State University of New York at Stony Brook, Stony Brook, NY.

Robinson, William E. 1987. Depuration of Heavy Metals in Hard Shell Clams and Other Marine Bivalve Molluscs. Edgartown Research Laboratory, New England Aquarium, Boston, MA.

Tweed, S. and Don Merrit. 1992. A Comprehensive Investigation of Larval Development and Mortality in the Eastern Oyster, Crassostrea virginica. New Jersey Sea Grant, Cape May, NJ.

Van Patten, P. 1989. Northeast Seaweed Culture. MIT Sea Grant, Cambridge MA.

Private Sources:

Aquaculture Innovation Center. 1992. Profile of the New England Shellfishery. Orono, ME.

Aspen Research and Information Center. 1981b. A Directory of Federal Regulations Affecting Development and Operation of Commercial Aquaculture. Aspen Systems Corporation, Rockville, MD.

Boston Magazine. April 1993. The Shell Game. pps. 114 - 118.

Burrell, V.G. Jr. 1985. Oyster Culture. pp. 235 - 273 in Crustacean and Mollusk Aquaculture in the United States, AVI Publishing Company, Westport, CT.

Chamberlain, G.W. 1986. 1985 Grow-out Research. Coastal Aquaculture 3(2): 7 - 8.

Chesapeake Bay Program. 1991. Report and Recommendations of the Non-Point Source Evaluation Panel. CPB/TRS 56/91, Annapolis, MD.

Conservation Law Foundation, 62 Summer Street, Boston, MA. 1988. Lost Harvest: Sewage, Shellfish, and EDconomic Losses in the New Bedford Area.

DiConti, Russell. July/August 1992. Coastwatch. Center for Coastal Studies, Provincetown, MA.

Firth, Frank E. 1986. Spanish Culture Methods, Mytilus Edulis. Encyclopedia of Marine Resources. Van Nostrand Rheinhold Company, New York, NY.

Gowen, J.JU. and N.B. Bradbury. 1987. The Ecological Impact of Salmon Farming in Coastal Waters: A Review. Oceanography and Mar. Biol. Annual Review. 25:562 - 572.

Hampson, Alfred A., Esq. March 1973. Legal Aspects of Aquaculture. Third Annual Technical Conference on Estuaries of the Northwest.

Hughes, J.T., J.J. Sullivan and R. Shleser. 1972. Enhancement of Lobster Growth. Science 177.

Massachusetts Audubon Society, 208 Great South Road, Lincoln, MA.

Manzi, J.J. 1985. Clam Aquaculture. pp. 275 - 310 in Crustacean and Mollusk Aquaculture in the United States, AVI Publishing Company, Westport, CT.

McCoy, Henry D. II. November/December 1989. Commercial Aquaculture Zones: A Legislative Proposal. Aquaculture Magazine.

Milne, P.H. 1972. Fish and Shellfish Farming in Coastal Waters. Fishing News, Ltd., London, England.

Murphy, Richard H. Title to Tidelands. 1980. 16 New England Law Review, pps. 110 - 115.

Pillay, T.V.R. 1976. The State of Aquaculture 1976. Surrey, England: Fishing News Books Ltd.

Richards, G.P. 1988. Microbial Purification of Shellfish: A Review of Depuration and Relaying. Food Protection 51(3): 218.

Shirley, Milford E. 1977. Mariculture: The Law of the Continental Shelf and Offshore Oil Recovery: A Technology Affected by a Body of Law Affected by a Technology. Open Sea Mariculture.

Shumway, S.E. 1990. A Review of the Effects of Algal Blooms on Shellfish and Aquaculture. Journal of the World Aquaculture Society 21(2).

Thompson, C. 1992. Profile of the Northeast Shellfishery. Aquaculture Innovation Center, Orono, ME.

Weston, D.P. and R.J. Gowen. 1988 Assessment and Prediction of Effects of Salmon Net-Pen Farming on the Benthic Environment. Report to the State of Washington Department of Fisheries, Olympia, Washington.

Wilson, J. and D. Fleming. 1989. Economics of the Maine Mussel Industry. World Aquaculture 20(4):49.

Personal Communications:

Paul Bagnelle, Edgartown Shellfish Officer

Donald Beers, Duxbury Shellfish Officer

Molly Benjamin, Provincetown Shellfish Commission

Samuel Bennett, Esq., Deputy General Counsel, Department of Environmental Protection

Priscilla Brooks, Resource Economist, Conservation Law Foundation

Lois Bruinooge, Esq. (formally with Coastal Zone Management, currently with Department of Environmental Protection)

Richard Emmett, Esq., Conservation Law Foundation

James Fair, Assistant Commissioner, Division of Marine Fisheries, Department of Fisheries, Wildlife, and Environmental Law Enforcement

Priscilla Geigis, Esq. Office of the Commissioner, Department of Fish, Wildlife, and Environmental Law Enforcement

J. Michael Hickey, Senior Biologist, Division of Marine Fisheries, Department of Fish, Wildlife, and Environmental Law Enforcement

K. Hunney, Biologist, Maine Department of Marine Resources

Richard Krauss, Aquaculture Research Corporation, Dennis, MA

Grant Kelly, Northeast Regional Engineer, U.S. Army Corps of Engineers, Waltham MA

John LaForte, Truro, MA

Dale Leavitt, Pg.D., Aquaculture Specialist, Woods Hole Sea Grant

Laurie Martinelli, Director of Public Policy, Massachusetts Audubon Society

Robert Nagle, Production Manager, <u>The John Nagle Company, Inc.</u>, Boston, MA

Russell Nagle, Distribution Manager, <u>The John Nagle Company, Inc.</u>, Boston, MA

Michael Parascandolo, Trapfish Division, <u>N. Parascandolo and Sons, Inc.</u>, Newport, RI

Karl Rask, Director, Massachusetts Aquaculture Association, Orleans, MA

Paul Sommerville, Wellfleet Shellfish Officer

Michael Syslo, Senior Biologist, Division of Marine Fisheries
Department of Fish, Wildlife, and Environmental Law Enforcement

APPENDIX I

FEDERAL LAW AND POLICY AFFECTING AQUACULTURE

Introduction.....

National Aquaculture Policy,
Planning and Development Act.....

Title XIV of the Agriculture and Food Act of 1980.....

Food Security Act of 1985.....

The Coastal Zone Management Act of 1972.....

The Lacey Act.....

The National Environmental Policy Act.....

The Federal Water Pollution Control Act.....

The Rivers and Harbors Act of 1899.....